

# Psychological Bulletin

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# Psychological Bulletin

## POPULATION DENSITY AND ENDOCRINE FUNCTION<sup>1</sup>

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Early evidence (Crew & Mirskaia, 1931) suggested that the population size of many mammalian species and especially of rodents is self-limiting. In 1952, Calhoun demonstrated density limitation in a confined population of Norway rats. The population he observed never exceeded 200, even though he estimated the growth potential in terms of shelter, space, and food to be well over 5,000. Subsequently, a number of studies have demonstrated that the reproductive capabilities of rodents living in high-density populations are impaired (e.g., Chitty, 1955; Christian, 1959c; Christian & LeMunyan, 1958; Hoffman, 1958; Kalela, 1957; Louch, 1956; Southwick, 1955a, 1955b; Strecker & Emlen, 1953). Research into the mechanisms by which density limitation is accomplished reveals an interaction between density, endocrine function, and behavior that has major implications for the behavior theorist working with animal subjects. This research is reviewed in the present paper.

In a rather comprehensive theory based on Selye's conception of a

general adaptation syndrome, Christian (1950) implicated the endocrine system in limitation of population density. He proposed that the observed triphasic population cycle consisting of an initial growth of population followed by a period of stability and then a period of decline could be accounted for by a stimulus feedback reaction described by Selye (1946), involving the endocrine system and particularly a pituitary-adrenocortical-gonadal axis. According to Selye, certain pituitary-adrenal-gonadal effects are produced by all general stressors and are in proportion to the severity of the stress. These effects consist in part of hyperactivity of the pituitary and adrenals and hypoactivity of the gonads. Christian reasoned that if population density were a stressor, it would be inversely related to gonadal activity and therefore to reproductive behavior, as well as to other factors affecting survival. Such relationships could account for the apparently self-limiting nature of density of population and would help to account for the triphasic population cycle. Under conditions of low density of population and in otherwise favorable circumstances, gonadal and reproductive activity would be high, resulting in an expanding population. The increasing population density, acting

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as an increasing stressor, would eventually reduce reproduction to the point that deaths would match births. The population would reach equilibrium at that point and would enter the second, stable phase of the population cycle. Such stability would be maintained until the population was subjected to an additional stressor, such as increased daylight or increased cold occurring with seasonal change. The additional stressor could destroy the equilibrium and precipitate a more or less rapid decline of population, partially by its effects on reproduction rate and partially by other lethal effects of the increased stress.

#### NATURAL POPULATIONS

Support for Christian's theory was provided by the discovery of a relationship between stages of the density cycle and adrenal weight in natural populations of Norway rats (Christian & Davis, 1956). Rats from 21 Baltimore city blocks were systematically sampled and their population numbers estimated over a period of months. Since the rats seldom cross streets, each block was essentially an independently varying population. At time of sampling, each of these populations was classified as belonging to one of five successive stages of a population cycle: low stationary, low increasing, high increasing, high stationary, and decreasing. Beginning with the low increasing stage, a progressive increase in adrenal size was found for the successive stages. The relationships in the low stationary stage were somewhat ambiguous, but perhaps appropriately so if it is remembered that this stage constitutes the end of the population cycle as well as its beginning. To the extent that adrenal size correlates with adrenal activity, the

results strongly suggest a progressive increase in stress, and in endocrine response to it, as the population cycle progresses. However, in this study, significant weight changes were not found in the thymus and pituitary glands, which normally show response to prolonged stress. Since nutritive elements were found in abundant amounts, social rather than strictly biological factors were presumed to be primary in determining the differences in adrenal weights. In a study of a rural population of Norway rats, Christian and Davis (Christian, 1959c) found a correlation of .90 between population density change and adrenal weight change. In this study, pituitary weight also changed with population size and correlated .99 with adrenal weight.

Louch (1956) reported similar findings in two natural populations of meadow voles. Population densities were estimated from monthly live trappings. In both populations, adrenal weight correlated positively with density. Eosinophil count, a blood-fraction measure known to vary inversely with adrenocortical activity, was found to have an inverse relationship to population density. The absence of apparent food shortages again suggested that non-nutritive factors were primarily responsible for the observed correlations.

#### POPULATION SIZE

Christian has suggested that a logarithmic relationship exists between size of population and the endocrine or related effects. A number of his laboratory and field researches support this contention. In one study (Christian, 1955a), he placed weanling male mice in groups of 1, 4, 6, 8, 16, and 32 for one week. Adrenal weight in all cases except for the



population of 32 showed a linear relationship to the logarithm of the population size. Adrenal weight for the largest population showed a decline from the next largest. This decline was initially interpreted as due to "social structure deterioration," representing some decrease in stress at the greatest density. More recently, however, Christian (1959c) has found that the relative decrease in adrenal weight at this high density is due to a loss in lipid content of the cortical cells, indicating an intense activation of the adrenocortex. The trend of increased adrenocortical activation with increased density would therefore appear to hold for all limits tested. Wild and tame mice show similar types of response to artificially established densities (Christian, 1955b), although both initial adrenal size and response to density is greater in the wild mice. Both responded to increased density by increased adrenal size, sex gland atrophy, and thymus atrophy (another index of stress).

Christian (1956a) found similar relationships in a study of free-growing populations of laboratory reared mice. Beginning with a few pairs in large cages amply supplied with food and water, some populations were allowed to reach an apparently self-determined asymptote. This was much below the number of animals that could be supported by the food and cover available. Other populations were allowed to reach approximately half of the expected maximal density of population. Still other animals were derived from segregated pairs and were maintained as segregated pairs following weaning. In the free-growing populations, the growth curves were sigmoid. Birth rate and survival of infants declined in proportion to the logarithm of the

size of the population. As was found in both the wild and the artificially constituted populations, increased adrenal weight was found to be associated with increased density of population. Histological examination revealed that the increase in weight was due primarily to hypertrophy and hyperplasia of the zona fasciculata, suggesting greater adrenocortical functioning. In the young male mice, part of the higher adrenal weight was due to delayed involution of the X zone, a transitory layer of the adrenocortex, found in young mice. Since this involution is brought about by androgens, the observed delay in involution suggests that androgen production, and therefore the onset of puberty, occurs at a later age in male mice from high-density populations. It further supports the assumption that a pituitary-adrenal-gonadal interaction system is involved in control of population density. Reproductive organs of the mature high-population-density males were also lighter and spermatogenesis was partially suppressed as compared with the low-density controls.

Other results implicating endocrine involvement in population control were also found. The decrease in survival rate of infants in the dense populations was attributed to deficient lactation of the mothers. The infants who died usually did so in 10 to 14 days after birth and were found to be uninjured but with empty stomachs. The survivors were weaned early, appeared grossly stunted, and were in poor condition. If production of prolactin, one of the gonadotrophic hormones of the pituitary, is suppressed, along with suppression of the other gonadotrophic hormones, then reduced lactation and the observed infant mortality and stunting would be expected. Suppression of the gonad-

otrophins would also account for the observed reduction in numbers of pregnancies and numbers of embryos per pregnancy in the denser populations and for the increase in numbers of resorbing embryos per pregnancy observed at autopsy. These suggestions are in general agreement with the recent findings of Helmreich (1960). In this case grouped female deer mice showed increased resorption of implanted embryos, although the incidence of pregnancy and the number of embryos implanted were not different from those of the isolated controls.

Of considerable interest is Christian's additional finding, consistent with Chitty's (1955) speculations, that the effects of decreased body weight, intrauterine mortality, decreased litter size, and reduced ability to lactate were still observable in the first and second generation offspring of grouped animals. The effects presumably were transmitted as a function of decreased, or nutritionally altered, milk supply of the mother.

Louch (1956) carried out a study of three freely growing but confined populations of meadow voles that in many respects parallels Christian's studies of house mice. During the period of observation, the three meadow vole populations had access to abundant food and nesting supplies. The growth curves were sigmoid, much like those found by Christian, although the rate of growth varied considerably among populations. Although number and size of litters were not significantly correlated with density, several other factors that tended to limit population size did vary as expected. Litter mortality was high under conditions of dense population. This was attributed to the mother's reduced ability

to lactate, to her greater tendency to eat or abandon her pups, and to increased trampling and disturbance of the litters by other animals. Adult mortality also correlated positively with size of population and was most pronounced during periods of population decline. The correlation was due at least in part to an apparent increased susceptibility to disease in dense populations. Amount of fighting and wounding increased with density. There was a tendency for fecundity, as measured by number of mice with scrotal testes or perforate vaginae, to correlate inversely with density. This inverse correlation was significant in one population, approached significance in another, and was opposite in sign and insignificant in the third. At high densities, males competed aggressively for females in heat, by chasing, fighting, and pushing each other away from the female. As a result, the number of mountings increased but few mountings led to completed copulation. Lowered eosinophil counts at the higher densities, together with the other findings, suggested, as do Christian's results, the direct involvement of the pituitary-adrenal-gonadal axis in the dynamics of population density.

Although many effects appear to follow a logarithmic relationship to population size, factors other than density alone can be important. Southwick (1955a) reports, for example, that different freely-growing populations of wild trapped house mice confined under essentially similar conditions varied as much as five fold in maximum size of population attained. He attributed the differences to uncontrolled social and genetic factors. Christian's finding (1955b) that wild mice show a more marked adrenal response to density than do laboratory mice suggests the

importance of genetic factors. Other investigators, while not questioning the fact of density limitation, have questioned whether or not size of population is the crucial variable. Several studies have been directed toward assessing possible alternative explanations.

#### WOUNDING AND SOCIAL RANK

In mice living 4, 8, or 16 to a cage, Southwick and Bland (1959) found no significant differences among the groups in adrenal weight unless wounded animals were compared with nonwounded. The wounded animals were found to have significantly heavier adrenals. They conclude that wounding is the essential operant in adrenocortical change and that higher density acts indirectly to increase adrenal size by creating a situation in which fighting and wounding is more likely to occur. Chitty, Chitty, Leslie, and Scott (1956) found similar evidence. Young male voles were put in contact with old mated pairs for periods of about 2 hours a day for several days. Fighting, chasing, and wounding typically occurred. The more severely wounded animals had a higher liver, spleen, and adrenal weight and a smaller thymus and body weight than did the less severely wounded. Clarke (1953), too, found similar effects when voles were introduced into cages containing a pair of "resident" animals. The newly introduced voles were viciously attacked and wounded; the longer the period of exposure, the more severe were their wounds and glandular changes. These studies implicate the physical effects of fighting and wounding as crucially important.

Contradictory results have been obtained in other studies, in which no relationship was found between

amount of wounding and adrenal size and in which glandular effects occurred with little or no fighting and no wounding at all. Christian (1959b) measured adrenal hypertrophy and presence or absence of scarring in 50 populations of four, five, or six albino male mice each. When adrenal weight was corrected for body weight, adrenal hypertrophy, found after 1 week of grouping, did not reflect either the severity of fighting or the amount of injury received. Barnett (1955), working with two strains of rats, took movies of fighting behavior, territoriality establishment, and the working out of hierarchies within groups. Histological examination of the adrenals revealed hypertrophy in the subordinate animals only; this hypertrophy was related to the social position within the group but not to the amount of fighting. Christian and Davis (Christian, 1959c) also found that dominant Norway rats showed little adrenal hypertrophy, even though they fought as much as or more than subordinate animals that did show adrenal change. Southwick and Bland (1959) found adrenal hypertrophy more likely to occur in males housed with females than in males housed with other males, even though fighting was not observed and wounding did not occur in either case. When wild male house mice were grouped six to a cage 4 hours a day for several days (Davis & Christian, 1957), a significant negative relationship was found between social rank and adrenal weight. A similar relationship was found by Vandenbergh (1960) using eosinophil levels and adrenal weights as indices of adrenocortical activity.

These studies suggest that social rank is an important factor in determining endocrine response. Amount

of wounding and social rank tend to be related in recently grouped populations, so that some correlation with wounding might be expected under some circumstances. Also, the height of the pyramid towering over a low-status animal, as well as the number of low-status animals, is a factor of the size of the population and would lead to an expected correlation between average endocrine response and population size. If social status were crucially important in determining the endocrine response, then the reproductive capacity and stress vulnerability of the low-status animals would be affected first in an expanding population. A selective advantage would therefore accrue to those characteristics making for high status in the population.

An interesting parallel appears between these data and data showing that hormonal variations in the blood stream are related to changes in dominance. If the initial status differences among animals are not too wide or too greatly solidified by learning, the administration of androgen to low-ranking normal and castrated animals increases the dominance status in both the male and the female (see Beach, 1948; Bindra, 1959).

#### LIVING SPACE

In studies of white Leghorn chickens, Siegel (1959a, 1959b, 1960) placed different numbers of birds in equal-sized pens and found that the more crowded groups had larger adrenals and produced fewer eggs. In some comparisons, he found smaller pituitary weights and histochemical evidence of greater adrenocortical secretion in the more crowded groups. Siegel ascribes these relationships to differences in floor space per animal. They are highly consistent with the data from rodent populations in re-

lating density to endocrine and reproductive response. In Siegel's studies, as in many of the rodent studies, population size and living space per animal are confounded, leaving open the possibility that size of population rather than living space is the crucial variable affecting endocrine response. Other studies tend to rule out the importance of living space as an independent variable. Christian found that the same positive relationship between population size and adrenal weight held for mice even when floor space was increased 42 times. In an unpublished study, we have found that the relationship held when living space per mouse was exactly equated, i.e., when a population of 10 animals was housed in twice as much space as a population of 5 animals and in 10 times the space of individually housed animals.

#### NOVELTY

A few studies have been concerned with the effect of stimulus change on endocrine response, on the assumption that a larger population offers the possibility of greater novelty and that novelty might be the important variable in the density studies. Christian and Davis (1955) tested the possibility that density reduction might be as stressful as density expansion. Rat populations in three Baltimore city blocks were reduced by trapping to about one-half of their estimated maximum and were maintained at that level for several months. An over-all reduction rather than increase in adrenal weight was found, suggesting that the population reduction was not stressful, at least as measured by changes in adrenal weight. It should be noted that possible transitory endocrine changes immediately following the density reductions were not measured.

A study by Siegel (1959c) also indicates that a density reduction is equivalent to a reduction in stress, as measured by adrenal weight regression. Twenty-five birds from each of two different groups of white Leghorn female chickens, housed 50 and 150 birds per pen, were sacrificed over a 15-day period. As expected, adrenal hypertrophy was more extensive in birds coming from the larger group. In both populations adrenal weights were significantly related to the day of sacrifice, with regression equations indicating that adrenal glands weighed progressively less as autopsies continued over the 15 day-period and population density decreased.

Vandenbergh (1960) found a transitory drop in eosinophil count following grouping of mice. This response, indicative of increased adrenocortical secretion, reached a peak approximately 4 hours after grouping and had largely disappeared by the second week. Change in adrenal weight was less rapid and less transitory. Christian (1959a) found an initial increase in urinary corticosteroid levels in guinea pigs following grouping, followed by a return to pregrouping levels within 3 days. Other investigators (Holcomb, 1957; Levine, 1959; Mason, 1959; Vogt, 1951) have found that almost any shift in stimulation will alter eosinophil and corticosteroid levels. It may therefore be that either a density increase or a density decrease would result in an initial rise in corticoid secretion, whereas only an increase in density would result in noticeable adrenal hypertrophy and other gross morphological changes. The possibly transitory stimulating effect of density reduction has not as yet been demonstrated, however. Some evidence that novelty is not the crucial

factor in the more persistent morphological changes associated with high density is the differentially greater response of the low-status animals (see previous discussion). It seems probable that the dominant animals encounter as many or more novel situations as do the more socially restricted low-status animals, and yet their glandular response is less.

#### EFFECT OF TRANQUILIZERS

One study has been done on the effect of tranquilizers on endocrine response to population density (Christian, 1956b). Mice receiving reserpine in their drinking water showed less extensive glandular alteration than did similarly grouped mice not receiving tranquilizer. The results are interpreted as supporting the hypothesis that the density-related changes in endocrine function are due to sociophysiological response to group pressures.

#### FEMALE ESTRUS CYCLE

Several studies have focused on the effect of population density on the female estrus cycle. van der Lee and Boot (1955, 1956) found that housing female mice four to a cage often prolonged by several days the normal 4 to 6 day occurrence of estrus. This temporary suspension of estrus of grouped females was confirmed by Dewar (1959), Lamond (1958, 1959), and Whitten (1956, 1957, 1958, 1959). Whitten (1959) reports suspension of estrus for as long as 40 days when females are grouped 30 to a cage, with the estrus cycles promptly returning when the mice are separated into individual cages.

These results suggest the possibility that prolonged female diestrus occurs in dense populations and is one mechanism of density control. There is, however, evidence that tends to



contradict such a conclusion. Whitten (1956, 1957, 1959) and Lamond (1959) have demonstrated that the introduction of a male into the female group or that the placing of a previously grouped female with a male will terminate the diestrus and will usually lead to pregnancy in a few days. Mating occurred predominantly on the third night after pairing when previously grouped females were placed with a male, indicating that contact with the male terminated a diestrus period and initiated an estrus cycle (Whitten, 1956, 1959). In contrast, matings with females previously housed individually were more randomly distributed among the first four nights, indicating the pre-existence of estrus cycles unrelated to the introduction of the male.

The ability of a male to terminate the diestrus of grouped females and the absence to date of reports of observed density-related increase in diestrus of females in mixed populations suggest that it is not a predominant factor in population control. The evidence nevertheless is consistent that the grouping of females results in diestrus, and this effect may be an important factor in determining the endocrinological or behavioral status of subjects used in laboratory settings. Whitten (1959) posits that some of the effects observed are mediated by the pituitary-gonadotrophic function, a theory that would relate these results closely to other observed effects of population density on endocrine function.

Controversy exists concerning the nature of the diestrus of the grouped females. Some investigators (Dewar, 1959; van der Lee & Boot, 1955, 1956) have attributed the diestrus to pseudopregnancy. Others (Lamond, 1959; Whitten, 1956, 1957, 1958)

consider the condition to differ in crucial respects from true pseudopregnancy, being easily terminable at any time by the introduction of a male, being associated with reduced weight of ovaries and uterus and with reduced number or absence of corpora lutea, and being accompanied by mucified vagina. With the possible exception of mucified vagina, none of these effects would be expected with true pseudopregnancy (Nalbandov, 1958; Turner, 1955).

Whitten (1957) argues that severe stress reactions are not present in the grouped females, since they appear healthy, retain their body weight, return to estrus rapidly upon isolation or pairing with a male, and become pregnant without apparent difficulty. Christian (1960) cites recent evidence, however, suggesting some endocrine response to grouping of females. As compared to isolated controls, he found mild hyperplasia of the adrenal fasciculata-reticularis zone in grouped females, suggesting increased ACTH production by the pituitary. He also cites other evidence suggestive of increased pituitary-adrenal response. The response was not, however, so great as that observed in groupings of males or of mixed sexes.

Present evidence suggests that olfactory cues are important in initiating diestrus in grouped females, in terminating diestrus, in controlling sexual behavior leading to pregnancy, and even in preserving or disrupting pregnancy after it occurs. Lamond (1958) and Whitten (1959) found that females housed singly but separated from each other only by a partition showed disruption of the estrus cycle. van der Lee and Boot (1956) found that olfactory bulb removal reduced the number of females that became diestrus under conditions of



grouping. Whitten (1956) found that mating of a grouped female could be shifted predominantly to the first night, instead of the third night, following pairing with a male if a male were enclosed within a small basket in the female cage for the 2 days prior to pairing or if the females were placed in a cage recently contaminated by males. Lamond (1959) reports that the number of litters born to anosmic mice is significantly smaller than for either normal or blinded animals. Bruce and Parrott (1960) report that pregnancy is blocked in a high proportion of recently mated intact female mice exposed to strange males, but not in anosmic females so exposed. Whether or not the olfactory cues that appear to mediate these effects operate through an effect on the pituitary-adrenal-gonadal system has not yet been established.

#### EFFECTS ON NONREPRODUCTIVE BEHAVIOR

If density of population affects endocrine function, then it will almost inevitably affect behavior studies. The relationships between population density and behavior will not be reviewed, other than briefly to indicate that the effects may be crucial for many studies. With regard to learning ability, for example, Marx (1956) found that grouped rats could learn a vigorous lever-pressing response faster than individually housed animals. With regard to "emotionality," Bovard and Newton (1956) found that rats living in a group showed more defecation and vocalization when transported by the experimenter. Much work has appeared and is appearing on the effects of early handling on later behavior. The evidence (e.g., Levine, 1959) that the early handling effects are

mediated by endocrine response to a "stressful" situation suggests the important role that endocrine function, and therefore population density, may have on such diverse variables as learning ability, survival, and brain chemistry. Clearly, the field is ripe for more experimental work. Also, clearly, the experimenter who draws his subjects haphazardly from colony cages containing varying numbers of animals is introducing into his study an uncontrolled variable that may crucially affect his obtained results.

#### SUMMARY

Population density has been shown to affect endocrine function, being positively related to adrenal hypertrophy and adrenocortical activity and negatively related to gonadal and mammary activity. Other factors being equal, many reactions appear to vary as the logarithm of the population size. However, there is some evidence that marked genetic differences in response exist as well as some evidence that population size is only indirectly a causative agent. Amount of wounding does not appear to be crucially important, although social rank, which at times correlates with amount of wounding, is a good predictor of individual response to population pressures. Mechanical restriction of living space appears to be unimportant within broad limits. Response to novelty may account for some transitory endocrine reactions but seems unlikely to be the crucial variable in less transitory morphological effects of population size. Grouping effects on female estrus cycle appear related more to olfactory cues and sexual composition of the group than to population density per se. One effect of the endocrine response appears to be an alteration

of reproductive capacity such as to provide a self-limiting control of population size. Learning ability, emotionality, and other behavior may also be altered by variations in density of population.

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## DOES THE HEART LEARN?

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In our time of cohabitation of various sciences one may wonder about the kind of affairs psychology has with some of the more firmly established disciplines. Other sciences may very well believe that the progeny of a relationship with psychology would necessarily be illegitimate. Or perhaps, at best, that psychology would have everything to gain and nothing to give. Must psychology be the protegee, or does it have unique techniques to share? It is the aim of this paper, by way of presenting some experimental findings, to suggest that certain techniques of modern psychology can be useful in the analysis of problems of cardiovascular physiology.

Detailed encouragement to the psychologist to use his techniques in the physiological laboratory comes from current adjustments in physiological thinking. Reviews of recent circulatory research by Rushmer (1955), Rushmer and Smith (1959), point out that the cardiovascular system is not altogether faithful to a few classical laws based largely upon simple hydraulic principles (Bainbridge, 1915; Patterson, Piper, & Starling, 1914). Rather it appears that this system is true to many principles roving about on several levels of analysis, among them the principles derived from conditioning procedures.

Gantt's translation of *The Internal Organs and the Cerebral Cortex* by Bykov (1957) could be the signal for a methodological revolution in certain phases of biological analysis and control, wherein the physiological reactions of the intact organism are

modified by conditioning techniques. Of particular interest in this book for our present discussion is the chapter on circulatory adjustments. Several experiments are cited wherein cardiac, vasomotor, and even splenic responses are conditional upon exteroceptive stimuli presented by the experimenter.

In contrasting the results mentioned in the Bykov book with those from other sources we are brought to what is perhaps the most paradoxical feature of cardiovascular conditioning, the form of the conditioned cardiac response. Granting that the heart does learn, just what is it that is learned?

### WHAT DOES THE HEART LEARN?

*CR-UCR Similarity.* Soviet investigators generally suggest that the conditioned response (CR) closely resembles the unconditioned response (UCR) as illustrated by an experiment of Petrova (Bykov, 1957). An auditory stimulus (whistle) was combined with intravenous injections of nitroglycerin. Because the act of injecting the fluid would act as a conditioned stimulus, its effect was extinguished with repeated intravenous injections of normal saline. The whistle, on the other hand, was always sounded after the nitroglycerin had been injected (but before the effect of the drug was manifest). After about 100 pairings of the whistle and nitroglycerin the whistle presented alone produced changes typical of those elicited by the drug (accelerated heart rate, decrease in QRS voltage, and augmented P and T waves).

Delov (Bykov, 1957) demon-

strated that a conditioned stimulus may produce a very different response from the above when combined a number of times with a drug of different consequences. In this experiment the conditioned stimulus (CS) was actually the stimulus complex associated with the injection, while the unconditioned stimulus (UCS) was a 0.2-gram injection of morphine. After 20 to 30 injections, the CS given without morphine produced the same changes in the electrocardiogram as those produced by morphine (deceleration in heart rate and marked reduction in the P deflection).

Additional experiments (Bykov, 1957) showing the similarity of UCR and CR for other drugs have been conducted by Samarin (strophanthin) and Levitin (acetylcholin and epinephrine).

Other investigators have taken a different view of the form of the heart rate CR. For example, in some experiments with human subjects by Zeaman, Deane, and Wegner (1954) and Zeaman and Wegner (1954), it was suggested that the CR resembles the UCR at the time of the UCS (shock) termination. In accord with this hypothesis a 2-second shock gave an accelerated heart rate CR and a 6-second shock gave a decelerated CR (since the UCR at shock termination was accelerating or decelerating, respectively). When other shock values were used in a later experiment (Zeaman & Wegner, 1958) this hypothesis was not upheld. It was predicted from the hypothesis that no conditioning would occur for a very short shock (0.1 second) which did not allow a change in heart rate before its termination, or for a very long shock (15 seconds) which allowed the heart rate to return to normal by the time it was termi-

nated. When conditioning did occur these investigators revised their hypothesis to suggest that to some extent large UCRs tend to give accelerative CRs and small UCRs decelerative CRs.

*Decelerative CR.* A decelerative heart rate CR in human subjects is consistently reported by Bersh, Notterman, and Schoenfeld (1953, 1956a, 1956b, 1956c, 1957a, 1957b; Notterman, Schoenfeld, & Bersh, 1952a, 1952b, 1952c). Their procedure was essentially the same as that used by Zeaman and Wegner (1954) with which a decelerative CR was obtained (1-second CS, 6-second CS-UCS interval, and a 6-second UCS). Their UCS shock level, however, was over twice that of the Zeaman and Wegner studies (30-volt alternating current as contrasted with 13-volt alternating current). For the most part, the measures indicating a decelerative CR were taken during the last two heart cycles of the CS-UCS interval. In answer to possible criticism that deceleration during this portion of the interval was not a representative CR, they also measured the first two heart cycles of the CS-UCS interval (Notterman et al., 1952c) and again found a decreasing heart rate, which was not, however, statistically significant.

Owens and Gantt (1950) report a decelerative CR when the petting of a dog served as the UCS. The UCR to this stimulation was also a reduction in heart rate. Mixed results regarding the form of the heart rate CR were obtained by Beier (1940). One subject showed an accelerative CR, another a decelerative CR, and still another, conditioned arrhythmia. The UCS used in this experiment was the working of a bicycle ergometer by the subject.

*Accelerative CR.* Other experiments

indicate a CR which is predominately accelerative in form. Skaggs (1926) used an auto horn CS and an induction shock UCS, separated by 1 minute, to produce a mild increase in human heart rate (1.1 beats/minute). A greater increase in rate was observed between the "normal" condition and the "expectancy" period preceding the CS (9.4 beats/minute).

Anderson and Parmenter (1941) demonstrated that the CR is an increase in heart rate when a buzzer or metronome CS is used with a shock pulse UCS. They further demonstrated "neurosis" in their sheep subjects with a discrimination procedure where only one of two stimuli was paired with shock. Neurotic subjects showed a higher and more irregular heart rate than normals in the experimental room, and gave an increase in heart rate to incidental stimuli whereas normals did not.

Moore and Marcuse (1945) ran two sows daily for 10 months using a tone CS and food UCS. They found a reliable increase in heart rate upon presentation of the CS, which preceded the UCS by 1 minute. Dykman and Gantt (1951) used a tone CS and a shock UCS, separated by 2 minutes, to produce an accelerative CR in dogs. As noted earlier, Zeaman and Wegner (1954), using a 2-second shock UCS, showed an increase in heart rate in human subjects with onset of the CS.

*CS-UCS Interval and Regularity.* Church and Black (1958) using dog subjects also found an accelerative CR with a tone CS and a 3-second shock UCS. Their results indicate that CR latency is shorter for a 5-second CS-UCS interval than for a 20-second CS-UCS interval. Latencies were virtually the same for the trace and delay conditioning procedures. No substantial differences

in heart rate were observed between the various experimental treatments. This last finding is to be contrasted with some results of Bersh, Notterman, and Schoenfeld (1953) who found that an irregular time between CS and UCS produced more "anxiety" (i.e., heart rate CRs of greater magnitude) than a regular time between. A condition where shock did not always follow the CS produced more anxiety than either of these conditions.

*Resistance to Extinction.* One particular disclosure from the Soviet cardiac conditioning work seems to be of special importance (Bykov, 1957). That is, the CR developed in pairing a neutral stimulus with a pharmacological agent is very hard to extinguish. For example, some 296 presentations of the CS alone were required by Petrova to extinguish the cardiac CR.

Gantt (Bykov, 1957) reports that a cardiac conditioned reflex to food may persist 2 years after the salivary and motor components have been extinguished. Notterman, Schoenfeld, and Bersh (1952c) found that irregular pairing of the UCS with the CS gave greater resistance to extinction than regular reinforcement. They report further (1952a) that when subjects could avoid the shock UCS with a skeletal response, extinction was more rapid than when subjects were told there would be no shock in extinction. Both of these treatments produced more rapid extinction than the regular extinction procedure. In a later experiment (Bersh et al., 1956c) found that the CRs of subjects who were forcibly restrained from making the skeletal avoidance response extinguished more rapidly than the free avoidance subjects.

*Generalization.* Stimulus general-



ization of the CS has been demonstrated by Dykman and Gantt (1951) whose dog subjects differentiated between 256, 512, and 1,024 cps tones with respect to heart rate, latency, and EKG amplitude. Bersh, Notterman, and Schoenfeld (1956c) obtained generalization across tone frequencies as a function of intensity of the UCS. For a 28-volt alternating current shock UCS the human *Ss* showed a greater CR (depression of rate) and a flatter generalization across the 1,920, 1,020, 480, and 180 cps tones than for a 20-volt alternating current UCS.

*CR across Trials.* Heart rate conditioning data collected by Dawson (1953) are perhaps the best source of information for changes in the form of the heart rate CR across trials. They also illustrate sharply how deceptive a simple label such as a rate "increase" or "decrease" is in describing the cardiac CR. So far as such details are reported, most of the studies discussed earlier involved no more than 11 conditioning trials (e.g., Church & Black, 1958; Notterman et al., 1952b, 1952c; Zeaman & Wegner, 1954, 1958). In the Dawson experiment 20 conditioning trials were used and the second by second forms of the CR and UCR are shown for each five-trial block. These results show that the early CR is, in effect, an acceleration followed by a deceleration to the level preceding the CS. At this stage of conditioning a comparison of rates preceding and following the CS will show a net increase no matter which point within the CS-UCS interval is selected. As conditioning trials continue, however, the decelerative phase of the CR becomes more pronounced, such that rate of the heart cycles during this phase is less than the rate preceding the CS. Hence, increase or decrease in heart rate as the CR

depends heavily upon the location within the CS-UCS interval one uses, as well as the trial number (or number of trials if trials are averaged). We may then add these factors to others which affect the CR, such as UCS length, CS-UCS interval, and the kind and intensity of the UCS.

#### INTERACTION WITH OTHER BODY SYSTEMS

A factor which appears in elementary physiology texts suggests that the heart, as such, may not learn at all. This factor, obvious enough perhaps to be invisible, is respiration. Recent quantitative data clearly show how breathing may affect heart rate (Clynes, 1960; Huttenlocher & Westcott, 1957). Both inspiration and expiration produce a biphasic cardiac response: a brief accelerative phase followed by a decelerative phase of longer duration. This biphasic cardiac response is of greater magnitude and has a shorter latency for inspiration than for expiration (Clynes, 1960). Furthermore, it has been demonstrated that in a classical conditioning situation involving buzzer and shock, conditioned deep inspirations occur with the onset of the CS, and that the cardiac CR is a brief acceleration followed by a more pronounced deceleration (Huttenlocher & Westcott, 1957).

Regardless of which portion of the respiratory cycle might be correlated with the CS, there is the frightful prospect that cardiac conditioning work thus far has, in fact, been unknowingly concerned with respiratory conditioning. Or, with some luck, cardiac conditioning has merely been contaminated by the respiratory variable.

Fortunately, at least one cardiac conditioning experiment has been reported in which respiration was con-

trolled. Westcott (1959) instructed subjects to breathe shallowly in time with a metronome during 10 CS (buzzer) alone trials and 10 conditioning trials when the CS and UCS (shock) were paired. The cardiac response in this experiment was a net drop in rate when the CS was given before conditioning, and a net increase in rate after the second conditioning trial. The conditioning curve was negatively accelerated across trials, showing an increase in heart rate over the pre-CS rate of 3.2 beats per minute on the last two trials. Respiration records showed consistent breathing on each trial, and across trials, for both frequency of respiration and the I/E ratios.

There are still other doubts about cardiac conditioning which we should consider. Kendon Smith (1954) argues that all conditioned visceral responses are in reality artifacts because they are brought on by activation of the skeletal musculature. According to this reasoning innate neural connections from the skeletal muscles activate the visceral systems with a muscular "bracing" to the UCS. Skeletal reactions are said to provide numerous afferent cues whereas "autonomic reactions generate no regulatory feedback whatever." Hence it is the skeletal system which is conditioned and the visceral system which merely accompanies. These ideas do badly in finding support from the cardiac literature discussing afferent pathways (e.g., Mitchell, 1956; Rushmer & Smith, 1959) for there is considerable anatomical evidence for autonomic feedback from the carotid and aortic bodies.

The opposite hypothesis, that skeletal responses can be mediated by autonomic responses is suggested by Wenzel (1959). Her data show an

increase in heart rate to tones associated with food and a decrease to tones associated with shock. Whether or not heart rate differentiation between the two conditions is related to autonomic mediation of skeletal responses is yet to be shown in the laboratory.

Church and Black (1958) argue a similar case which is in line with Pavlov's "inhibition of delay." They too suggest autonomic mediation of skeletal responses. The tabulated latencies in their experimental report, however, tend to show shorter skeletal than autonomic latencies, which, after all, are consistent with the time constants of the two systems.

Perhaps the complexity of the organism is such as to preclude such simple cause and effect hypotheses about the various systems.

#### CONCLUSION

That the activity of the heart will change significantly in amplitude and rate in the presence of conditional stimuli is clear enough. There appear, however, to be mixed emotions as to the form of the heart rate CR since some authors report an increased rate, others a decreased rate, and still others either increased or decreased rate, depending on such factors as the UCR. The original question might then be what does the heart learn rather than does it learn? It is suggested that an answer to the second question may be found at two locations: at the desk, where heart rate changes would be treated as analog events rather than simple up or down events, and, at the laboratory, where like problems have previously been untangled with parametric study.

Some tentative principles have been abstracted from the papers reviewed:

1. Both form of the EKG cycle

and heart rate may be conditioned with the classical paradigm.

2. Latency of the heart rate CR is less for a shorter CS-UCS interval.

3. A CR of greater magnitude is produced when the UCS irregularly follows the CS.

4. CR resistance to extinction is great when some pharmacological UCSs are used. Resistance to extinction is increased with irregular CS-UCS pairings, and is decreased when UCS avoidance is made contingent upon a skeletal response.

5. There is a generalization gradi-

ent across tone frequencies as a function of UCS intensity.

6. The heart rate CR changes across trials such that the dominant accelerative portion of the response decreases as the decelerative portion increases.

Whether it is "really" the heart that learns, or something else such as the respiratory or the skeletal system, is perhaps a matter of degree. It seems unlikely that a particular bodily system is completely free from the influence of other bodily systems.

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## MATERNAL DEPRIVATION: TOWARD AN EMPIRICAL AND CONCEPTUAL RE-EVALUATION<sup>1</sup>

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The significance of early infantile experience for later development has been reiterated so frequently and so persistently that the general validity of this assertion is now almost unchallenged. An extensive literature on deviating patterns of maternal care, loosely labeled "maternal deprivation," adds up with an impressive consistency in its *general* conclusions: deviating conditions of maternal care in early life tend to be associated with later disturbances in intellectual and personal-social functioning. It has been difficult to build on this general premise in formulating more precise research hypotheses relating specific variables of early maternal care to later developmental characteristics. If one attempts to order the empirical data from the many studies and the varied contexts, it becomes apparent that the concept of maternal deprivation is a rather muddled one. Maternal deprivation has been used as a broad descriptive term as well as an overall explanatory concept. As a descriptive term it encompasses a variety of conditions of infant care which are phenotypi-

cally as well as dynamically very different. In this review of the research and theoretical literature, our major objective is to clarify the concept of maternal deprivation by identifying the basic variables and concepts which have been indiscriminately combined under this term.

Previous reviews have dealt primarily with the findings (Bowlby, 1951; Glaser & Eisenberg, 1956), or with the methodology of a few studies (Pinneau, 1950, 1955). The chief effort of this review will be directed towards sorting out on an empirical level the varied antecedent conditions of maternal care described in the literature, and relating these empirical conditions to some major theoretical concepts. Through this kind of analysis, it is hoped to facilitate the formulation of more explicit hypotheses on the relationship between specific aspects of early life experiences and later development.

### EMPIRICAL ANALYSIS OF THE RE- SEARCH ON "MATERNAL DEPRIVATION"

In the literature on maternal deprivation, four different kinds of deviations from a hypothetical mode of maternal care have been included: institutionalization; separation from a mother or mother-substitute; multiple mothering, in which there is no one continuous person performing the major mothering functions; distortions in the quality of mothering, e.g., rejection, overprotection, am-

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bivalence. In very few studies do we find these "pure conditions." Most often several conditions occur concomitantly or sequentially in complex interaction, e.g., separation is followed by institutionalization, multiple mothering occurs in an institutional setting.

Tables 1 to 4 present the chief research studies organized in terms of the major conditions of early care: institutionalization, separation, multiple mothering. Studies on distortions in the mother-child relationship, e.g., rejection, overprotection, ambivalence, on which there are many clinical reports, but few research reports, have not been included. The studies presented in the tables are grouped according to their general research designs: retrospective, direct, or contemporaneous. The tables point out the major characteristics of the samples: the population from which the subjects were chosen, the ages at the time of study, and the ages at the time of the experience. Also presented are the major techniques used in data collection or the kinds of data obtained. For the retrospective studies, the presence or absence of data on earlier conditions of maternal care is noted. Finally, overlapping or contaminating conditions are noted where they have been reported.

It is clear from the tables that the major share of studies has been on institutional care. There are many fewer published reports on separation and multiple mothering. In the following section, in considering each of these types of studies, our focus will be on an analysis of the environmental conditions and the impact of these events and conditions on development. Throughout we will attempt to integrate the empirical data in terms of some basic psychological

concepts, and to point up some hypotheses amenable to research.

#### INSTITUTIONALIZATION

Most of the generalizations about the effects of "maternal deprivation" are based on retrospective research in which institutionalization has been a major background condition. The general research designs of the many retrospective studies reported between 1937 and 1955 are basically similar and tend to suffer from similar methodological deficiencies. In all but a few studies there is a sampling bias due to the method of selection of cases; subjects are chosen from clinic populations of cases under treatment for emotional or personality disturbances. (In delving back into the history of these patients, it was discovered that many had spent some part of their earlier life in an institutional setting.) Perhaps the most significant deficiency in many of these studies is the lack of specific data on early conditions of maternal care. The characteristics of the institutional environment are unknown or not described, and no data, or, at the best, very meager data are given about the circumstances associated with institutionalization. Such significant information as age at time of placement, duration of institutional care, traumatic conditions preceding or concomitant with institutional placement is rarely given. Frequently information about experiences following institutional care is scant and of uncertain validity. The data on the personality characteristics of the subjects also vary greatly in depth and adequacy; much data are derived from psychiatric diagnoses based on an unspecified number of interviews or consist of case history material from unspecified sources; in a few



instances, projective or other kinds of personality tests have been used.

#### *The Institutional Environment*

In much of the research on institutions the environment has been dealt with so grossly that "institutionalization" has often referred to a setting as broad in many respects as "the home." Only a few contemporaneous studies of infants and young children give sufficiently detailed descriptions of the institutional setting to enable one to isolate discrete variables. Only one study, comparing the institutional and home environments of a small group of infants, makes a serious attempt to give an objective description of an institution (Rheingold, 1960).

The institutional environments in the direct studies can be ordered in terms of several theoretically meaningful categories which can be further reduced to specific research variables.

*The physical environment—quality and amount of sensory stimulation.* The importance of sensory stimulation for development has recently been emphasized by a number of animal experiments. In most of the research, institutional settings are characterized in the extreme as lacking in sensory stimulation; they are described as colorless and drab with little visual or auditory stimulation and with few objects for the child to manipulate.

*The emotional environment—affective stimulation.* For research, the emotional environment can be defined in a restricted sense in terms of formal, measurable aspects of affective stimulation, i.e., intensity and variability. Institutions tend to be characterized by an emotional blandness and a lack of variation in feeling tone with the result that the infant is

not exposed to strongly negative or strongly positive affective stimulation.

*The social environment—social stimulation.* The amount of mothering, the quality and consistency of mothering, and the amount and quality of general social stimulation are major aspects of the animate environment in terms of which institutional care is defined. Most of the studies describe a low adult-child ratio, averaging about one adult to 10 infants in institutional settings. There are usually many different caretakers, with the result that the infant has little opportunity to relate to one person as a consistent source of gratification. Compared with an infant in his own home, the research indicates that in institutions there is much less mothering contact, less total social stimulation, and less stability in mother-figures.

*Learning conditions.* Learning conditions which deviate from those in a "normal" home environment are reported characteristic of institutions: deviations in opportunities for acquiring or practicing new skills, deviations in motivational conditions, and in scheduling. Often infants are confined to the crib or playpen during most of the day, with very limited opportunity to practice emerging motor skills or to make perceptual discriminations. There tends to be little recognition by adults for positive achievements, with no or inconsistent reinforcement for positive learnings or socially desirable responses. Daily routines are sometimes characterized by an element of unpredictability, but more often routines are rigidly scheduled with little variation from day to day, and with little adaptation to individual differences.

It is clear that institutionalization

TABLE 1  
RESEARCH ON INSTITUTIONALIZATION: DIRECT STUDIES OF CHILDREN IN INSTITUTIONS

Investigator	Subjects	Age at time of study	Age when institutionalized	Techniques or type of data	Description of environment
Brodbeck & Irwin (1946)	Institutional: 94 Controls: 217	Birth to 6 months	Birth to 6 months	Analysis of speech sounds	General—social, emotional
Brown (1937)	Institutional: 200 Controls: 200 from "poor" home environments	9-14 years	Broad range: birth to adolescence	Brown Personality Inventory	No data
Dennis & Najarian (1957)	Institutional: 49 infants; 30 preschool age Controls: 41	2-12 months 4½-6 years	Birth	Infant tests Goodenough Draw-A-Man Test	Detailed—physical, social, learning conditions
DuPan & Roth (1955)	Institutional: 14	4-30 months	Birth to 3 months	Gesell test	Detailed—physical, social, learning conditions
Fischer (1952)	Institutional: 62	6-7 months	Birth to 3 months	Cattell test	Detailed—physical, social
Flint (1957)	Institutional: 16	2-20 months	Birth to 6 months	Observation Infant security scale Observation	Detailed—physical, social, learning conditions
Freud & Burlingham (1944)	Institutional: approximately 90	Birth to 2 years	Early infancy—no specific data	Clinical observation	General—physical, social
Gesell & Amatruda (1941)	Institutional: unspecified number	Longitudinal Birth to 2 years	No data	Gesell test	No data
Goldfarb (1945a)	Institutional: 15 Controls: 15	First test mean: 34 months Follow-up mean: 43 months	Early infancy: mean—4½ months	Intelligence tests Language test Test of motor coordination Social maturity scale Rorschach Behavior ratings	General—physical, social
Levy (1947)	Institutional: 101 Foster home <sup>1</sup> controls: 129	122 under 6 months 34: 6 to 12 months, 74 over 12 months	Early infancy	Gesell test Stanford-Binet and other preschool intelligence tests Vineland Social Maturity Scale	Detailed—physical, social

TABLE 1 (Continued)

Investigator	Subjects	Age at time of study	Age when institutionalized	Techniques or type of data	Description of environment
Rheingold (1936)	Institutional: 16 8 controls, 8 experimental given special mothering	6-8 months	Early infancy	Cattell test Social responsiveness test	Detailed—physical, social, emotional
Skeels, Updegraff, Wellman & Williams (1938) Wellman & Pegram (1944)	Institutional: varying numbers of cases, main group 53 controls; 35 experimental, given preschool experience	14 to 54 years	Birth to 2 years	Intelligence test Language test Motor tests General information test Vineland Social Maturity Scale Behavior observations	Detailed—physical, social, emotional
Skeels & Dye (1938) Skeels (1942)	Institutional: 25 12 controls; 13 experimental given special stimulation	First test: controls—12 to 22 months experimental—7 to 36 months Last test: controls—5 to 9 years experimental—4½ to 9½ years	Birth to 2 years	Intelligence tests 4 follow-up tests	Detailed—physical, social, emotional
Spitz (1946)	61 infants in founding home; 69 infants with own mothers in prison; 34 infants in own homes	Early infancy to 2½ years	Birth	Hetzer-Wolf Infant Test Clinical observation	Detailed—physical, social
Spitz & Wolf (1949)	170 infants with own mothers in prison; 61 infants in founding home; 17 infants in own homes	Birth to 15 months	Birth	Observation Interview Hetzer-Wolf Infant Test Rorschach (mothers)	General—physical, social; detailed personality of mothers

is not a simple variable, and cannot be used as a simple research variable or explanatory concept. Even in the limited sample of institutions found in the direct studies, the environments are not identical. Qualitative as well as quantitative variations are apparent among institutions in the amount of sensory stimulation, in the consistency of mothering, in the consistency of rewards, etc.

*Intellectual, Personality, and Social Characteristics Associated with Institutionalization*

Despite the methodological inadequacies and the great range of antecedent conditions in the research, there is a core of consistency in the findings on the characteristics of children, adolescents, and adults with institutional backgrounds. The major characteristics associated with institutional care are: general intellectual retardation, retardation in language functions, and social and "personality" disturbances, chiefly disturbances centering around the capacity to establish and maintain close personal relationships. Within the overall consistency, however, there is significant variation. Not all children with institutional experience give evidence of intellectual or personality damage, and there is a range in the extent of injury. These variations can sometimes be related to the characteristics of the environment; sometimes significant modifying or interacting variables can be identified.

*Intellectual defects.* General intellectual retardation is commonly found in older children and adolescents with a history of institutionalization (Bender, 1947; Goldfarb, 1945a; Levy, 1947; Lowrey, 1940) as well as in infants and young children growing up in institutional environments

(Dennis & Najarian, 1957; Fischer, 1952, 1953; Gesell & Amatruda, 1941; Skeels, Updegraff, Wellman, & Williams, 1938; Spitz, 1945, 1946). The data do not, however, permit the simple conclusion that gross intellectual deficiency is a necessary consequence of institutional experience. The incidence and degree of retardation vary considerably from one study to another. In only some of the studies do some children show severe retardation (Dennis & Najarian, 1957; Gesell & Amatruda, 1941; Goldfarb, 1945a, 1945b; Skeels et al., 1938; Spitz, 1945, 1946). In others there is only relative retardation; they are functioning on a dull-normal level (DuPan & Roth, 1955; Fischer, 1952, 1953; Freud & Burlingham, 1944; Klackenburg, 1956; Rheingold, 1956). Several factors seem to be related to the varied outcomes in intellectual functioning:

1. The amount of individualized stimulation provided in these environments seems to be significantly related to the degree of retardation. In the institutions in which attempts were made to provide individualized stimulation, and to foster a relationship between a single caretaker and infant, severe retardation was not found (DuPan & Roth, 1955; Fischer, 1952, 1953; Freud & Burlingham, 1944; Klackenburg, 1956; Rheingold, 1956).

2. The age of the child at the time of institutionalization varies greatly among the studies; several investigators have concluded that the younger the child at the time of institutionalization, the more likely is subsequent retardation (Bender, 1945, 1947; Beres & Obers, 1950; Goldfarb, 1947). The evidence is meager, consisting of data from two studies. In Goldfarb's research in which a large percentage of cases showed evidence

of retardation, the mean age of admission to the institution was 4.5 months, with only three cases over 1 year of age. Of a group of 37 adolescents and young adults studied by Beres and Obers (1950) only four were mentally retarded; all four had entered the institution under 6 months.

3. Constitutional factors. There are no direct data, but the findings that, in seemingly identical environments, some children show retardation and others do not, have been interpreted as evidence of constitutional differences in vulnerability to institutional deprivation.

4. The duration of institutionalization. The data point to a cumulative impact of the institutional environment on intellectual functioning. In most studies, with continued institutional residence, infants show a progressive drop in developmental test quotients (Dennis & Najarian, 1957; Fischer, 1952, 1953; Freud & Burlingham, 1944, no test data; Skeels, 1942; Skeels & Dye, 1939; Spitz, 1945, 1946). A few studies (DuPan & Roth, 1955; Rheingold, 1956; Rheingold & Bayley 1959) report no significant cumulative loss in intellectual functioning. Although Dennis and Najarian (1957) found a decrease in Cattell test scores in institutionalized infants between 3 and 12 months they discovered no significant retardation on the Goodenough Draw-A-Man Test among a group of older children, 4.5 to 6 years of age, who had been in the same institution for several years. They raise the interesting question as to whether an environment which fails to offer adequate intellectual stimulation to infants is necessarily retarding for preschool children.

The direct association between intellectual retardation and environ-

mental impoverishment is dramatically emphasized by Skeels and Dye's study (1939). Retarded institutional children made significant gains in intellectual functions after special environmental stimulation. In another study (Skeels et al., 1938), the intellectual stimulation provided by an experimental nursery school in an institution was found effective in preventing deterioration in intellectual functioning. Whereas a control group showed cumulative losses in IQ scores, children given nursery school experience maintained their IQ level.

Two other studies suggest that intellectual retardation need not be attributed to some elusive, unknown aspect of the institutional environment, but can be directly related to lack of adequate stimulation. Rheingold (1943) studying infants in boarding homes found that children who shared the home with several other babies had significantly lower developmental test scores than infants who were "only children" in the boarding homes. Coleman and Provence (1957) observed retardation similar to the institutional pattern in children living in very unstimulating home environments.

Analysis of the separate aspects of intellectual functioning indicates that all functions are not equally affected by institutional living. Consistent evidence of retardation is found in language, in time and space concepts, and in capacity for abstract conceptualization.

*Language* is one function in which severe retardation has been found repeatedly in institutionalized infants and young children (Brodbeck & Irwin, 1946; DuPan & Roth, 1955; Fischer, 1952, 1953; Freud & Burlingham, 1944; Gesell & Amatruda, 1941; Skeels et al., 1938; Rheingold &

Bayley, 1959) as well as in older children and adults with an institutional history (Bender, 1945, 1947; Goldfarb, 1945a; Haggerty, 1959; Lowery, 1940). There is disagreement in the literature on institutionalization only in the age at which language functions first seem to be affected. Brodbeck and Irwin (1946) found evidence of retardation in institutionalized infants in the first few months of life, whereas Freud and Burlingham (1944) report no indications of language retardation before 12 months. Brodbeck and Irwin's data were based on careful phonetic analysis of speech sounds, whereas Freud and Burlingham had no systematic language data on infants.

With regard to the etiology of language retardation, Fischer (1952, 1953) notes that in many institutions there is little reinforcement by adults of the infant's vocalizations, and consequently reduced opportunity for the child to acquire the signal functions and expressive functions of language. Recent data on the conditioning of vocalizations in infants (Rheingold, Gewirtz, & Ross, 1959) give evidence of the role of reinforcement in young infant's vocalizations. Early studies of language development (Day, 1932; Van Alstyne, 1929) pointed to a direct relationship between amount of environmental stimulation (e.g., number of hours the child was read to, "extensions of the environment") and vocabulary and sentence length in preschool children. On the simplest level, language retardation, like general intellectual retardation, can be related to inadequate language stimulation. Lack of motivation for imitative behavior may interact with inadequate reinforcement of speech sounds in determining language retardation.

Serious defects in time and spatial concepts in older children have been reported in clinical descriptions by Goldfarb (1945a, 1949) and Bender (1945, 1947). Poor memory for past events is linked by Bender with such character defects as inability to benefit from past mistakes, lack of future goals, and weak motivation to control behavior for future gains. Goldfarb relates social maladjustment to difficulties in time and spatial concepts. As a result of these conceptual difficulties, disregard of school and family rules occurs.

*Disturbances in abstract thinking* were also found by Bender (1947) and Goldfarb (1943b) in school aged children and in adolescents with an institutional background. Goldfarb (1945b) describes as characteristic of these children "an unusually defective level of conceptualization . . . manifested in difficulty in organizing a variety of stimuli meaningfully and in abstracting relationships" (p. 251). On the Rorschach test, adolescents with an institutional background showed "an unusual adherence to a concrete attitude and inadequate conceptualization" (1943a, p. 222).

*Motor functions.* Motor development seems to be less significantly affected than any other aspect of development, although there are markedly discrepant reports. DuPan and Roth (1955) and Fischer (1953) conclude that there is no significant retardation in motor development during the first year among institutionalized children. Freud and Burlingham (1944) report accelerated development during the early part of the second year, while Spitz (1946) notes marked retardation in motor functions during the first and second years. Differing opportunities for the exercise of developing motor functions in different institutional



TABLE 2  
RESEARCH ON INSTITUTIONALIZATION: RETROSPECTIVE STUDIES

Investigator	Subjects	Age at time of study	Age when institutionalized	Duration of institutionalization	Techniques or type of data	Data on early experiences	Contaminating conditions
Binder (1947)	5000 clinic cases	Preadolescence	Birth to middle childhood	Range: not specified	Case history Psychiatric diagnosis	General retrospective	Repeated separations Rejection
Bender & Varnell (1941)	250 clinic cases	1-6 years	Birth to 6 years	Range: not specified	Intelligence tests Case history	General retrospective	
Beres & Obers (1950)	37 clinic cases with institutional background	Adolescence and adulthood	Birth to 12 months	Varying periods up to 4 years Average: 3 years	Case history Psychiatric diagnosis Intelligence test	Detailed case history	Separation and rejection
Bodman et al. (1950)	51 cases with institutional background 52 controls	Early adolescence	16 cases under 2 years Average: 4.4 years	Range from 3 to 15 years Average: 9.6 years	Vineland Social Maturity Scale Case history	General data on variety of institutions	High incidence of mentally defective and disturbed patients Several changes in institutions
Goldfarb (1943b)	20 children with institutional background 20 foster home controls	6-10 years Follow-up	1 to 24 months	3 years	Baruch Preschool Checklist Newell Problem Checklist	General retrospective data	Repeated separations from foster mothers
Goldfarb (1945b)	15 children with institutional background 15 foster home controls	Mean: 12 years	Early infancy	2½ to 3 years	Intelligence tests Concept formation tests—Weigl Goldstein-Scheerer Clinical assessment of personal and social functioning	Some retrospective data	Repeated separations from foster mothers
Goldfarb (1944)	40 children with institutional background 40 foster home controls	Mean: 7½ years Follow-up	Early infancy	Average: 34 months	Analysis of problems and reasons for placement	Some retrospective data	Repeated separations from foster mothers Maternal rejection
Goldfarb (1947)	15 well-adjusted and 15 poorly adjusted children with institutional background	Mean: 14½ years	Poorly adjusted mean: 5.8 months Well-adjusted mean: 10.9 months	Poorly adjusted: 34 months Well-adjusted: 25 months	Caseworker's ratings on adjustment	Detailed retrospective data	Repeated separations
Goldfarb (1949)	18 institutional clinic cases 13 clinic cases 15 foster home	Mean: 12 years	Early infancy mean: 4½ months	Group average: 39 months	Rorschach test Intelligence test	No data	Not reported
Haggerty (1959)	100 social agency cases with institutional background	Mean age: 12.7 years	"First few years of life"	Average: 3½ years	Analysis of language samples	No data	Separation
Lowrey (1940)	28 psychiatric clinic cases with institutional background	Range from 3 to 6 years	Range from 2 weeks to 34 months	Range from 6 to 42 months	Case history Intelligence tests	Variable retrospective history	Repeated separations

settings may be involved (Skeels et al., 1938).

Both extremes in *activity level* are found in institutionalized infants. Hyperactivity is sometimes noted (Fischer, 1952) but more common is a lowered activity level, associated with the general passivity noted as part of the pattern of intellectual retardation. There are only vague indications in the data of some factors which may account for these different findings: constitutional differences among infants, the age or developmental level at the time of institutionalization, and the length of institutionalization. For instance, in the initial stages of institutionalization, hyperactivity is often found, with lowered activity level more common after prolonged institutional residence.

*Motor disturbances* in the form of bizarre stereotyped motor patterns suggestive of neurological damage have been reported by Spitz (1946) in infants after a long period of institutional residence; similar but less extreme motor disturbances were noted by Fischer (1952, 1953). In older children, Bender (1947) and Goldfarb (1943a, 1945b, 1947) found hyperkinetic behavior, a pattern considered part of a syndrome of impulsivity, with psychogenic rather than neurogenic bases.

The findings on deviant motor patterns and the data on defects in conceptual thinking suggest the possibility of central nervous system damage as a result of institutionalization. The evidence is not very strong, however, nor are there clear bases in these data for hypothesizing the conditions under which irreversible neurological damage might occur.

*Social and personality disturbances.* Although the institutional syndrome has most frequently been described in

terms of social and personality disturbances, in many respects the data are less clear than are the findings on intellectual development. Personality data are based primarily on clinical impressions, and the characteristics described are usually at the extreme end of the scale, reflecting exaggerated pathology or a complete lack of capacity, rather than a relative deficiency.

*Interpersonal relationships.* The major deviations reported in the literature are in the area of interpersonal relationship. Two overtly dissimilar, but dynamically related, types of interpersonal disturbance have been described: social apathy manifested by indifference to social attachments, and "affect hunger" characterized by incessant and insatiable seeking of affection. Several retrospective studies report a syndrome in older children and adolescents described as an inability to establish close, warm personal relationships (Bender, 1947; Bender & Yarnell, 1941; Goldfarb, 1943a, 1945b, 1949; Lowrey, 1940), a personality pattern labeled the "affectionless character" by Bowlby (1944), and one which Bender (1947) identifies as a psychopathic behavior disorder.

In the contemporaneous studies of infants in institutions, social apathy is described in terms of several specific response patterns:

1. Inadequate social responsiveness, as evidenced by a complete lack of social initiative, by withdrawn or apathetic response to social approaches (Bakwin, 1949; Fischer, 1952, 1953; Freud & Burlingham, 1944), or in depressed scores on the social sector of developmental tests (DuPan & Roth, 1955; Fischer, 1952, 1953)

2. An indifference to social attachments, manifested by lack of any

significant attachments or meaningful relationships with caretakers in the institution (Freud & Burlingham, 1944; Rheingold, 1956)

3. Inadequate social discrimination as evidenced by failure to give differentiated responses to strangers and familiar caretakers (Freud & Burlingham, 1944)

4. A lack of normal social sensitivity, indicated by inability to respond discriminatively to different kinds of emotional expression (Freud & Burlingham, 1944)

The specificity of the relationship between social stimulation and social responsiveness in infancy is pointed up by Rheingold's data (1956). Infants in an institution who were given intensive social stimulation by one mother-figure, from the sixth to the eighth month of life, showed significantly greater social responsiveness than control subjects cared for by the more usual institutional routine. General developmental progress was not affected, however, by this special type of stimulation. In a follow-up of these children in adoptive homes at 19 months of age, Rheingold and Bayley (1959) found no evidence of any lasting impact of this special experience.

The syndrome of "affect hunger" characterized by indiscriminate and insatiable demands for attention and affection is less common than social apathy. It is reported in several retrospective studies (Bender, 1945, 1947; Goldfarb, 1945b; Lowrey, 1940), but in only one contemporaneous study (Freud & Burlingham, 1944), in which children in an institution are described as "exacting, demanding, apparently passionate, but always disappointed in new attachments" (p. 58). A similar, but less intense pattern of indiscriminate sociability among 6-8

month old infants was observed by Rheingold (1956). Freud and Burlingham also noted in infants an associated pattern of exhibitionism, involving indiscriminate display of themselves before strangers.

Behavioral deviations considered symptomatic of disturbances in ego and superego development have been reported in older children (Bender, 1945, 1947; Beres & Obers, 1950; Goldfarb, 1943a, 1949; Lowrey, 1940). Frequently noted is a pattern of diffuse and impulsive behavior suggesting a lack of normal inhibitory controls. In these children overt antisocial and aggressive behavior is often found. Bender and Goldfarb both note a lack of normal anxiety or guilt about aggression, a low frustration tolerance, a lack of goal-directedness, and low achievement motivation. Goldfarb (1943a) summarizes the personality pattern as impoverished, meager, and undifferentiated, deficient in inhibition and control. Even as late as adolescence, the institution children show the simple, unrefined, undifferentiated kind of behavior typical of preschool children.

Beres and Obers (1950) is the one psychiatrically oriented study which raises some question as to the extent of personality damage resulting from institutionalization. They note a similar underlying pathology in all cases—a distortion in psychic structure, an immature ego, and deficient superego development—but conclude that by late adolescence about half of their 37 cases were making a favorable overt adjustment. They were

functioning well, whether in work situation or at school . . . and presented no evidence of overt disturbance in their behavior or in their relationships within their families or among friends (p. 228).

This study points up the problem for research of making a valid distinction between mental health and pathology. These conclusions illustrate sharply the conflict between a definition of mental health based on overt behavior and a definition derived from a psychodynamic assessment of strengths and liabilities.

In looking to the direct studies for clues to the antecedents of personality deviations in older children, one is disappointed by the limited data on the personality characteristics of infants in institutions. The meager data on infants suggest some precursors of defective ego and superego development such as failure to show imitative behavior at the appropriate developmental period (Freud & Burlingham, 1944; Fischer, 1953). The conflicting findings on autoerotic activity emphasize the lack of agreement as to what constitutes normal behavior in infancy. Freud and Burlingham (1944) as well as Fischer (1952, 1953) describe a high incidence of thumbsucking, rocking, head-banging in young infants, and masturbation in older children. Spitz and Wolf (1949), on the other hand, found "practically no autoerotic activities" among the infants in the foundling home. They hypothesize that an emotional relationship between the child and a mother-figure is a prerequisite for the appearance of autoerotic activities.

Few direct studies give information on the age at which personality disturbances first become evident. In most of this research, the youngest children are over 6 months at the time of study. Where younger children have been studied, frequently no data are given on social or personality characteristics. Only two studies offer data on the age at which personality disturbances are first

noted. Freud and Burlingham (1944) note that infants in their institution did not show signs of social retardation before 5 months. Gesell and Amatruda (1941) report first signs of "social ineptness" evident at 24 weeks.

The one experimental study on human infants (Dennis, 1941) is often cited as evidence that early sensory and social deprivation need have no impact on development. Dennis found no significant retardation in a pair of twins who were given "minimum" social and sensory stimulation during the first 7 months of life. Stone (1954) on the basis of a careful analysis of a later report (Dennis & Dennis, 1951) suggests that minimum stimulation probably represented minimal adequate stimulation, much more than that provided in many institutional environments. In Dennis' study the infants were handled for the normal routines, and there was a consistent mother person. The fact that these conditions did not continue much beyond the first half year may also be significant.

Many ad hoc theories have been offered to account for the intellectual and language retardation, the specific defects in abstract thinking, and the varied social and personality disturbances associated with institutionalization. The explanations which offer "maternal deprivation" as the basic etiological entity tend, on the whole, to be vague and generalized, and offer little basis for systematic research. With regard to abstract thought, Bender (1946) states:

The earliest identification with the mother and her continuous affectional care is necessary during the period of habit training and the rapid development of language and the formation of concepts within the family unit. Otherwise the higher semantic and social development and the expansion of the educational capacities does not take place (p. 76).

(Quoted by permission of Child Study Association of America.)

Regarding time concepts, she speculates, "It appears that we develop a concept of time in the passage of time in our early love relationships with our mother" (p. 96). Kardiner (1954) suggests that the sense of time develops in relation to the child's activities in looking forward to gratification. Goldfarb (1955) hypothesizes that lack of an adult identification model (in institutions) inhibits the development of functions such as language, which are dependent on social forms of imitation and communication. Impairment in abstract thinking is interpreted (Goldfarb, 1955) in terms of Stern's theory (1938) which postulates that the development of conceptual thinking is dependent on the growth of a sense of continuity of the self. According to Stern, the grasp of identity, as well as judgments of equality, similarity, and difference are all derived from the sense of continuity of self. At first these judgments are related to concrete personal events; eventually, they are separated from them and become abstract. Without continuity of mothering in an institution, Goldfarb contends the normal development of the self-concept is impaired, with resulting defects in abstract thought processes. Social and personality disturbances are linked directly to lack of opportunity for close human relationships in infancy in institutional environments. Goldfarb attributes defective ego and superego development to inadequate opportunity for the child to identify with parental figures and to internalize the parental image. Bender (1946) describes the etiology of personality disturbances in similar terms:

There is a primary defect in ability to identify in their relationships with other people . . .

due to the fact that they never experienced a continuous identification during the infantile period from the early weeks through the period when language and social concepts of right and wrong are normally built up and when psychosexual and personality development are proceeding (p. 76). (Quoted by permission of Child Study Association of America).

She hypothesizes that anxiety and guilt arise in reaction to "threats to object relationship or identification processes" (p. 76). Lack of anxiety and inability to feel guilt are related to the lack of capacity to identify or form object relationships.

Analysis of environmental variables in the research literature points to some more discrete factors than maternal deprivation in the institutional setting. This elusive variable, maternal deprivation, can be analyzed in terms of variables more amenable to research, e.g., amount and quality of tactile, auditory, or visual stimulation; reinforcement schedules; etc. Harlow's (1958) research on infant primates has demonstrated the efficacy for research of analyzing mothering in terms of simple stimulus conditions, such as contact stimulation. The discrepancies in the findings of the research on institutionalization suggest the need to consider interacting variables, such as constitutional differences in vulnerability, varying sensitivities at different developmental stages, etc., in formulating hypotheses for more critical research testing.

#### MATERNAL SEPARATION

Maternal separation has never been studied under pure conditions. Most often separation has been associated with other traumatic events such as illness and hospitalization or operative procedures, and often with parental rejection or death or disability of a parent. Frequently sepa-

TABLE 3  
RESEARCH ON MATERNAL SEPARATION

Investigator	Subjects	Age at time of study	Age at time of experience	Techniques or type of data	Data on early experiences	Contaminating conditions
Ainsworth & Boston (1952)	One case	Observation: 3 years Follow-up tests: 5 to 6 years	13 months	Rorschach A-I Stanford-Binet Weigl-Goldstein Sorting Test Goldstein-Scheerer Cube Test	Retrospective report	Hospitalization for tuberculosis
Berg & Cohen (1959)	40 schizophrenic women in mental hospital 40 neurotic women	20-40 years	Birth to adulthood	Case history	Limited retrospective data	Rejection
Bowlby (1944)	44 juvenile thieves	5.7 to 17 years	Birth to adolescence	Case history Psychiatric diagnosis	Variable retrospective data	Institutionalization Rejection
Bowlby (1953b)	49 children in residential nurseries or hospitals	12-48 months	12-24 months	Clinical observation	Direct observation	Institutionalization Rejection Hospitalization for illness
Bowlby, Ainsworth, Boston, & Rosenbluth (1956)	60 children with previous sanatorium experience 57 controls	6-14 years	Range: Birth to 4 years	Intelligence test Clinical evaluation by teacher, psychologist, psychiatrist, social worker	General retrospective data	Rejection Hospitalization for tuberculosis
Edelston (1943)	42 children hospitalized for illness	2½-15 years	Range from early infancy	Clinical observation	Limited retrospective data	Illness Rejection
Heinicke (1956)	Children in residential and day nurseries	15-31 months	12-30 months	Standardized observation and doll play	Direct observation	None reported
Lewis (1954)	500 children in reception center	Under 5 to over 15 years	Birth to adolescence	Clinical assessment	Variable retrospective data	Institutionalization Rejection
Robertson & Bowlby (1952)	Unspecified number of children in hospitals	18-24 months	18-24 months	Clinical observation	Direct observation	Hospitalization
Roundineco, David, & Nicolae (1952)	20 children placed in institution	12-17 months	12-17 months	Clinical observation	Direct observation	Institutionalization
Schaffer (1958)	76 infants in hospital for illness	3-51 weeks	3-51 weeks	Cattell Infant Test Standardized observation Home follow-up	Direct observation	Illness Hospitalization
Spitz & Wolf (1946)	123 children in a nursery	14 days to 18 months	5-7 months	Clinical observation	Direct observation	None reported



ration from the parents has been followed by institutional placement with the result that the impact of institutional influences is superimposed on the loss of parental figures. In the literature on separation, the role of such contaminating variables has not been distinguished from the effects of a break in continuity of relationship with the mother. Spitz and Wolf's (1946) is the only study in which the physical environment remained unchanged following separation; it is one of the few studies in which the quality of the mother-child relationship prior to separation had been studied.

Most of the research is contemporaneous, reporting on the reactions of children at the time of separation. The long-term effects are almost unknown. Follow-up data more than a year later are given in a few studies (Bowlby, Ainsworth, Boston, & Rosenbluth, 1956; Lewis, 1954; Spitz, 1954a, 1954b; Spitz & Wolf, 1946), but in these studies there are many contaminating conditions, e.g., severely disturbed parental relationships, repeated separations, intermittent institutionalization.

#### *Immediate Reactions to Separation*

Despite the many different conditions associated with the separation experience, there is some degree of consistency in the findings reported on immediate and short-term reactions of infants and preschool children to separation. In each of the studies some children develop apparently severe reactions, and the behavior sequences in these extreme cases appear to be dynamically similar (Bowlby, 1953b; Robertson & Bowlby, 1952; Roundinesco, David, & Nicolas, 1952; Spitz & Wolf, 1946). The characteristic sequence of responses begins with active protest

and violent emotional reactions, such as intense and prolonged crying and active reaching out to people, in apparent attempts to bring back the mother or to find a substitute. In time this behavior is followed by active rejection of adults, and finally by apathy and withdrawal of interest in people, accompanied by a decrease in general activity level. Robertson and Bowlby characterize this latter phase as "mourning"; Spitz and Wolf label it "anaclitic depression." Feeding disturbances—refusal of food, sometimes pathological appetite—and regression in motor and other functions are also reported. When the mother is not restored, Spitz found symptoms of progressive deterioration in infants, a complete withdrawal from social interaction, a sharp drop in developmental level on infant tests, and extreme physical debilitation, with loss of weight and increased susceptibility to infections. In older children (over 12 months) marked physical and intellectual deterioration have not been reported, but severe disturbances in interpersonal relationships have been noted (Bowlby, 1953b; Robertson & Bowlby, 1952). The "mourning phase" in infants and young children is followed by behavior described as a "denial of the need for his own mother," which Robertson and Bowlby interpret as an indication of a repression of the mother image. The child shows no apparent recognition of his own mother, but may transfer his attachment to a substitute mother. (There has been some controversy as to whether such behavior can be interpreted as evidence of repression or whether it should be considered more simply as a denial mechanism—Bowlby, 1953a; Heinicke, 1956.) If no substitute mother is available, the child may show promiscuously

friendly behavior, using adults in an instrumental way, but without establishing meaningful attachments. Such behavior Bowlby considers indicative of a repression of all need for mothering, the prelude to a psychopathic character development. If, however, the child is reunited with his mother before the need for mothering is completely repressed (after some unstated critical time interval) the behavior pattern is believed to be reversible. The child is able on return to his mother to re-establish a relationship with her, although there may be several months of difficult adjustment, with irritability, impulsive expression of feelings, and an exaggeratedly intense attachment.

These descriptions of the reactions of young children to conditions involving loss of a mother-figure have provided the basis for most of the generalizations about the severe effects of maternal separation. The dramatic character of these changes has overshadowed the significant fact that a substantial portion of the children in each study did not show severe reactions to separation. In Spitz's study of 123 infants separated from their mothers between 6 and 8 months of age, severe reactions occurred in only 19 cases. Although in Robertson and Bowlby's (1952) research on 45 children ranging in age from 4 months to 4 years, all but three are reported to have shown some reaction; the intensity and duration of the reactions are not clearly specified. Less than half, 20 cases, are reported as showing "acute fretting," a behavior pattern which is not well-defined. The reported duration of the reaction varied from 1 to 17 days. There are no data on the number of children who showed prolonged reactions.

In a careful study of the reactions to hospitalization of 76 infants under 1 year of age (ranging from 3 to 51 weeks) Schaffer (1958) found that reactions varied with age. Infants over 7 months of age showed overt social and emotional reactions, such as excessive crying, fear of strangers, clinging and overdependence on the mother. Infants under 7 months evidenced more global disturbances, i.e., somatic upsets, blank facial expression, extreme preoccupation with the environment. Schaffer relates the global disturbances to sensory deprivation, whereas the social disturbance at the later age, an age at which more differentiated relationship with the mother exists, are interpreted as reactions to separation from the mother.

Heinicke's research (1956) points to less severe effects of simpler, less complicated separation situations. He found no extreme behavioral disturbances in two groups of children, 15 to 30 months of age, with different separation experiences, one group in a residential nursery, the other in a day nursery. The children in the residential nursery did show more overt and more intense aggression, greater frequency of autoerotic activities, and more frequent lapses in sphincter control. These findings are interpreted as indicating an imbalance between the child's impulses and his power to control and organize these impulses in relation to the external world.

#### *Long-Term Effects of Separation*

Conclusions about the long-term effects of separation are very tenuous. They are based on a few studies in which the information about the early history is not well-documented.

In an earlier study of 44 juvenile thieves, Bowlby (1944) concluded

that separation experiences in childhood resulted in a character disorder distinguished by a "lack of affection or feeling for anyone." The conclusions are based on clinical findings that 12 out of 14 cases diagnosed as "affectionless characters" had been separated from their mothers in infancy or early childhood. Some of these children had been hospitalized for illness without any contact with their mothers over a long period of time, others had experienced frequent changes in foster mothers, and some had been institutionalized for long periods during infancy.

In a follow-up study of 60 children between 6 and 13 years of age, who had been in a sanitarium for tuberculosis for varying periods of time before their fourth birthday, Bowlby et al. (1956) found less serious long-term effects than in the earlier studies. No statistically significant difference in intelligence was found between the control and the sanitarium group. In personality characteristics, the sanitarium children were judged as showing tendencies towards withdrawal and apathy, as well as greater aggressiveness. On the basis of the psychiatric social worker's interview with the parents, 63% of the children were rated as maladjusted, 13% were considered well-adjusted, and 21% adjusted but with minor problems. Bowlby et al. conclude that "outcome is immensely varied, and of those who are damaged, only a small minority develop those very serious disabilities of personality which first drew attention to the pathogenic nature of the experience" (p. 240). They suggest that the potentially damaging effects of separation should not be minimized, but concede that "some of the workers who first drew attention to the dangers of maternal deprivation resulting from separation

have tended on occasion to overstate their case" (p. 242).

The findings of Lewis (1954) are sometimes cited as evidence that early separation need not necessarily have lasting harmful effects. Among a group of 500 children who were studied in a reception center shortly after being separated from their parents, only 19 showed "morbid lack of affective responsiveness" (p. 41). Follow-up data were obtained on 240 of these children, 2-3.5 years later. Only 100 had a personal follow-up by a psychiatric social worker and a psychiatrist; information on the others was obtained through letters from social workers who had some contact with the children. Of the 100 more intensively studied children, only three were diagnosed as having marked personality disorders, 22 were having some difficulties in relationships, and 36 were showing mild neurotic symptoms or mild delinquent behavior. With reference to the timing of separation, Lewis concludes that "separation from the mother before the age of five years was a prognostically adverse feature" (p. 122). Apparently this is a clinically based conclusion, since the data presented in the tables show no significant differences between the children separated before 5 years of age and those separated after 5.

Data from several studies indicate that the impact of separation is modified by the character of the mother-child relationship preceding the separation experience and the adequacy of the substitute mothering following separation. Spitz and Wolf (1946) noted that the infants who did not develop severe depressive reactions were those separated from "poor mothers," and conclude that the better the mother-child relationship preceding separation, the

TABLE 4  
RESEARCH ON MULTIPLE MOTHERING

Investi- gators	Subjects	Techniques	Age at time of experience	Age at study	Data on early experiences
Rabin (1957)	38 children from kibbutz and 34 controls from neighboring villages	Rorschach	Birth to time of study	9-11 years	General description of environment
Rabin (1958a)	24 infants and 40 children in kibbutz 20 control infants and 40 control children	Rorschach Vineland Social Maturity Goodenough Draw-A-Man Griffiths Infant Scale	Birth to time of study	9-17 months 9-11 years	General description of environment

more severe the immediate reactions. Lewis (1954), on the other hand, found a higher proportion of children who had been separated from normally affectionate mothers in "good" or "fair" condition than those who had not received "adequate" affection. It might be hypothesized that a close relationship with a mother-figure preceding separation will be followed by more severe immediate reaction but will be ultimately more favorable than a poor antecedent relationship. Children who have experienced a close relationship in infancy may be better prepared to form new attachments in later life than children without any experience of close relationships.

The amount, the quality, and the consistency of substitute mothering will presumably influence the intensity of immediate reactions as well as the long-term personality consequences. Spitz and Wolf (1946) concluded that infants who were provided with a satisfactory substitute mother did not develop the depressive syndrome. (There were no independent criteria of the adequacy of substitute mothering. The substitute relationship was considered satisfactory in those cases which did not develop depressive symptoms.) Robertson and Bowlby (1952) also note that where an adequate substitute mother was provided, there was not a complete withdrawal from social contact.

#### MULTIPLE MOTHERING

Serious personality difficulties in later life have been postulated as a consequence of multiple mothering in infancy and early childhood. There has been little research, and in most of the clinical observations multiple mothering has been associated with impersonal or rejecting mater-

nal care. The underlying assumption in much of the literature is that inadequate maternal care is a necessary concomitant of situations in which there is more than one mother-figure. Multiple mothering has never been very precisely defined. In its most general sense, it refers to an environmental setting in which a number of different persons perform the maternal functions for the child, with varying degrees of adequacy and with varying degrees of consistency. From the child's viewpoint, it may mean that there is no single person to whom he can relate as a major source of gratification and on whom his dependency needs can be focused. In some situations the biological mother may share the mothering functions with other chosen women; in other circumstances no biological tie exists between the child and the several mothers. Some current studies in home management houses, a few reports on the Israeli kibbutzim, and a very few anthropological reports provide all the available data on the effects of multiple mothering.

In the anthropological accounts of multiple mothering in different cultural contexts (DuBois, 1944; Eggan, 1945; Mead, 1935; Roscoe, 1953) there are variations in the number of people who share mothering functions as well as variations in the role of the natural mother. In cultures in which the extended family is the traditional pattern, the mothering functions may be shared by the mother, grandmother, aunts, and other female relatives of the child; in some groups, male relatives may take over some maternal functions. The biological mother may be clearly identified as the central, most significant person in some cultures; in others she may be assigned a very secondary role.

In Western cultures, grandmothers

frequently assume some of the mothering functions, and in some social groups, child nurses play an important role. In the pre-Civil War Southern plantation class group, many mothering functions were taken over by the Negro nurse. The line of demarcation between supplemental maternal care and multiple mothering has never been very clear.

In none of these situations are disturbances in infant functioning associated with multiple mothering practices, nor are later personality characteristics or deviations attributed to this aspect of early maternal care.

The Israeli kibbutzim provide an unique set of conditions of multiple mothering. In this setting, there are two mother-figures, the natural mother and the metapelet, the children's caretaker, each of whom has very distinctive functions. The major share of the daily routine care as well as major training functions, such as toileting and impulse control, are assumed by the caretaker in the communal nurseries. The mother's contacts with the child tend to be limited to scheduled periods during the day, which are free periods and do not involve traditional family routines. The mother seems to function solely as an agent to provide affectional gratification, although obviously the extent of the mother's influence, as well as the specific areas of influence on the child's development, will vary with her concept of her role and with her personality characteristics.

There are several impressionistic reports (Golan, 1958; Irvine, 1952; Rapaport, 1958) and a few systematic studies (Rabin, 1957, 1958a) of the development of infants and children in the Israeli kibbutzim. Rabin (1958a), using the Griffiths Infant



Developmental Scale, found slight developmental retardation in infants between 9 and 17 months of age living in a communal nursery. In only one sector of development—the personal-social area—were these infants significantly retarded. Rabin attributes this retardation to less individual stimulation in the kibbutzim as compared to a normal home environment. This study represents the only reported research in a setting in which there may be deprivation in the amount of stimulation without concomitant lack of affectional interchange with the mother.

In an attempt to assess the long-term effects of living under these special conditions of maternal care in the kibbutz, Rabin (1958a) studied a group of children, between 9 and 11 years of age, who had lived in this environment from infancy. He found no evidences of retardation (using the Goodenough Draw-A-Man Test), nor were there any indications of personality distortions. On the contrary, Rorschach data are interpreted as indicating that the children from the communal settlements showed "better emotional control and greater overall maturity." In ego-strength (using Beck's index) they were judged superior to the control group of children living with their parents. Rabin interprets these findings as evidence of the important role of later experiences in personality development.

In another study, Rabin (1958b) compared the psychosexual development of 10-year-old kibbutzim reared boys with boys from patriarchal type families. Using the Blacky test, he found significant differences, consistent with theoretical expectations. The kibbutz boys showed less "oedipal intensity," more diffuse positive identification with their fathers, and less intense sibling

rivalry. This study also points up the fact that multiple mothering is only one of the significant factors which differentiate the kibbutz from the "normal" family setting. As in the case with other conditions associated with maternal deprivation the kibbutz is atypical in regard to the absence of the father.

Home management houses provide a setting in which multiple mothering occurs without associated deprivation of social stimulation. These houses are set up in university home economics departments to provide practical experience in child care for the students. The infant is separated from his foster mother or removed from a familiar institutional environment and placed in the home management house for a period of several weeks to several months. He is cared for by a number of young women, each of whom assumes primary responsibility for mothering activities for a limited period of time, usually about one week. There is one continuous figure—the instructor in the house—with whom the infant can maintain a relationship; she assumes some of the ordinary child care functions. In the course of his residence in the home management house, the infant may have 15 to 20 different "mothers." In this setting he receives much attention and stimulation from many different "mother-figures." Following his residence in the home management house, the infant is usually placed in a foster or adoptive home. The follow-up studies and the several direct studies of children in home management houses (Gardner, Pease, & Hawkes, 1959; Gardner & Swiger, 1958) are in agreement in finding no evidence of intellectual retardation and no gross personality disturbances. The long-term effects have not yet been evaluated.



These three settings—the home management house, the kibbutz, and the extended family—are comparable in only one respect; the mothering functions are distributed among several different persons. They differ in regard to the continuity of the mother-figure, in the role played by the substitute mothers, and in the amount of social stimulation given to infant. In some situations, because of the high adult-child ratio, it is likely that the infant will receive more sensory as well as more social stimulation than the child in an average family home. For infants, the kibbutz may be similar to an institutional setting in terms of the amount of individual social stimulation provided. It is clear that none of these conditions necessarily involves severe deprivation of mothering, but the mothering experience of children in these settings may differ significantly from that of children in homes with one mother-figure.

None of these studies provides a crucial test of the prevalent hypothesis that multiple mothering results in a diffusion of the mother-image. This theory, developed in the context of institutional care, holds that the child who is cared for by a number of different persons cannot develop a focused image of one significant mother-person in infancy, and consequently, will have difficulties in relationships in later life. On the whole, the few relevant pieces of research suggest that multiple mothering per se is not necessarily damaging to the child.

#### DISTORTIONS IN THE MOTHER-CHILD RELATIONSHIP

Although distortions in the mother-child relationship have frequently been included in the concept of maternal deprivation, in this report we

shall not attempt any comprehensive review of this vast clinical literature. Institutionalization, separation, and multiple mothering represent deviations from a cultural norm of "mothering" primarily on the dimension of amount or consistency of contact with the mother. Under the category of distortions in the mother-child relationship are subsumed all the deviations in maternal relationships which usually have as their antecedents disturbances in the character or personality of the mother. These disturbances in maternal relationships are manifested in overtly or covertly hostile or rejecting behavior, sometimes more subtly in overprotective behavior, and often in unpredictable swings from affection to rejection or in ambivalent behavior. As distinguished from a lack of social stimulation, a lack of responsiveness, and the lack of a mother-figure, this type of deviation in maternal care tends to be characterized by either very strong emotional stimulation, or by stimulation with a preponderance of negative affect. In contrast to institutional care, there may even be very intense intellectual stimulation.

The literature on distorted maternal relationships suggests a somewhat different kind of personality outcome from the psychopathic or affectionless character. The personality distortions tend to be in the schizophrenic, depressive, and neurotic categories. Again there may be rather specific antecedent conditions and organismic vulnerabilities associated with these types of personality deviations (Spitz, 1951). A critical review pointed towards a clarification of the variables and an analysis of the many ad hoc theories concerning distorted mother-child relationships is very much needed.

### SOME THEORETICAL ISSUES AND RESEARCH IMPLICATIONS

The data from the research on institutionalization, maternal separation, and multiple mothering have relevance for a number of fundamental issues in developmental theory: questions concerning the kinds of environmental conditions which facilitate, inhibit, or distort normal developmental progress; the conditions which influence the reversibility of effects of events in infancy and early childhood; and the extent to which the timing of an experience, i.e., the developmental stage at which it occurs, determines its specific impact.

In theories of the effects of early infantile experiences on later development, two concepts have been prominent: deprivation and stress. Although all the intricacies of the mother-child relationship cannot be conceptualized adequately in terms of these concepts, some of the environmental conditions and events found in the research on maternal deprivation can be ordered meaningfully in these terms. Deprivation is a key concept in the analysis of institutional environments. Many of the circumstances associated with maternal separation and multiple mothering can be ordered in terms of the concept of stress.

#### *Deprivation*

In institutional settings several types of deprivation, each with potentially different developmental implications, can be distinguished: sensory deprivation, social deprivation, and emotional deprivation. In many settings all three types of deprivation occur and are complexly interrelated, but they do not necessarily vary concomitantly, and they

can be independently manipulated in research.

The studies on sensory deprivation in animals indicate that complete restriction of perceptual experience in early life results in permanent impairment in the functions in which deprivation occurs. In the most extreme institutional environments the degree of sensory deprivation is less severe than in the animal studies. Nevertheless, developmental retardation is found, with the extent of retardation corresponding to the degree of sensory deprivation.

Social deprivation probably acts in a similar way as deprivation of sensory stimulation, leading to disturbances in social functioning, such as, social apathy and social hyperresponsiveness. The simplest hypothesis relates social apathy to inadequate social stimulation during a developmental period which is critical for the acquisition of social responsiveness. If social deprivation occurs after appropriate social responses have been learned, affect hunger or intensified seeking of social response may occur. Although social deprivation is less amenable to experimental manipulation than is sensory deprivation, in natural situations, some simple indices can be used, such as the number of persons with whom the infant has contact during a 24-hour period, the amount of time during which he receives stimulation.

Emotional deprivation has been used popularly and in clinical writings as a catchall term to include deprivation of social, sensory, and affectional stimulation. For research, a more precise usage in terms of deprivation of affective stimulation may be useful. The term, emotional deprivation, can be restricted to characterize an environment with neutral feeling tone or without variation in feeling

tone, an environment similar in some respects to the monotonous, bland environment described under sensory deprivation. Emotional apathy, withdrawn behavior, lack of differentiation of affect, and insensitivity to feelings or emotional nuances in others are characteristics which might be related to early emotional deprivation. Within this concept of emotional deprivation, simple objective measures are also possible, e.g., ratings of intensity of positive or negative affect, amount of time during a 24-hour period in which different types and intensities of affective stimulation are provided.

In addition to independent manipulation of each of these types of stimulation—sensory, social, and emotional—in more focused research there might be systematic variation in several dimensions of stimulation: quality of stimulation, e.g., monotonous, varied; intensity; frequency; regularity; cumulative duration of deprivation; sensory modalities in which deprivation occurs.

#### *Stress Consequent to Change*

Critical research on maternal separation requires a distinction between the event of separation and later conditions often associated with separation which may be similar to those described under deprivation. The event of separation is associated with significant changes in the physical, and social environments, changes which may be stressful for the young child. In the physical environment, the changes involve the disappearance of familiar objects, sounds, smells, and tactile stimuli; in the social environment, there may be changes in the amount and quality of social stimulation. The new environment may provide more tactile stimulation and less verbal stimula-

tion. There may be modifications in the speed as well as kind of response to the child, e.g., the new caretaker may ignore the child's crying, or she may reward it by tactile stimulation rather than by oral gratification. For the infant or young child, these changes result in a loss of environmental predictability. The degree of stress experienced is likely to vary with the degree of unpredictability.

Change and novelty as stress inducing agents can be studied through research designs providing for careful measurement or systematic variation in the physical and human environments, i.e., the degree of carryover of familiar objects from the old to the new environment, the degree of similarity between the old and new caretakers in physical and psychological characteristics, variations among the old and new mothers in the modalities in which stimulation is given. The impact of change in the physical environment might be evaluated by holding constant the human environment while systematically varying the physical environment, and conversely, the human environment might be varied, with the physical environment constant. The amount of change necessary to produce a discriminable difference to the child may vary with developmental factors. The significance of a change in the human environment will almost certainly depend on whether a meaningful relationship has developed with the mother-figure. If separation occurs after this point, the stress of change is reinforced by the loss of a significant person.

In the research on multiple mothering the one consistent characteristic of the varied contexts of multiple mothering is environmental unpredictability associated with changing agents of gratification. Unpredicta-

bility may be based on differences in technique among the different mother-figures, on variations in speed of response to the child's expression of needs, on inconsistency in the kinds of behavior which are rewarded, punished, or ignored. Unlike separation conditions in which new predictable patterns may soon be established, in multiple mothering unpredictability remains the most characteristic aspect of the environment.

There is not strong research evidence nor very firm theoretical grounds to support the assumption that the presence of several concurrent mother-figures in early life results in a diffusion of the mother-image and later inability to establish meaningful relationships. The variable conditions of reinforcement which characterize some multiple mothering situations provide a special kind of learning situation which may lead to the development of atypical patterns of relationships, but not necessarily shallow ones. It is likely that the presence of several mother-figures will vary in significance at different developmental periods. The lack of a consistent role model is probably more serious during the early preschool period than in early infancy. In further research, attempts should be made to vary systematically the degree of stress associated with environmental unpredictability, while controlling other variables such as degree of role differentiation among the multiple mothers.

Although deprivation and trauma can be treated as independent concepts, there are conditions under which deprivation can be considered a traumatic stimulus. It is recognized that trauma may result from excessive stimulation, but the conditions under which inadequate stimulation may be traumatic are more

obscure. Recent research indicates that extreme sensory deprivation may be stressful for adults (Wexler, Mendelson, Leiderman, & Solomon, 1959). We might assume that deprivation becomes a traumatic stimulus after the appropriate motivational conditions have developed. Thus Hebb (1955) suggests:

The observed results seem to mean, not that the stimulus of another attentive organism (the mother) is necessary from the first, but that it may become necessary only as psychological dependence on the mother develops (p. 828).

### *Research Implications*

Analysis of the research on institutionalization, separation, and multiple mothering highlights some theoretically significant questions and points to some specific variables which can be experimentally manipulated or controlled through the opportunistic utilization of natural situations.

*Duration of deprivation or stress.* In much of the research, the subjects have experienced a cumulative series of deprivations or stressful experiences, beginning in infancy and continuing through childhood. Few studies give specific data on the length of time the child has been exposed to these conditions. Goldfarb (1945b, 1947, 1955), Bender (1945, 1947), and Bowlby (1944) conclude from retrospective studies that the longer the period of institutional care, the more severe the ultimate damage. These conclusions are based largely on individual case findings. Those cases which did not show the same irreversible patterns as the rest of the population had been in institutions for a shorter period of time. Spitz and Wolf (1946) suggest that there may be a critical time interval after which the effects of maternal separation are irreversible.

If the infant is reunited with his mother within 3 months, the process of physical, social, and intellectual deterioration may be arrested, but if the mother-child relationship is not restored within 5 months, irreparable damage occurs. There are no comparable data on children beyond infancy. One might hypothesize that the critical time interval might be longer with older children.

Research on older children attest to the damaging effects of repeated separations (Bowlby, 1944; Lewis, 1954). On the whole, no distinction has been made among several different separation experiences: a single instance of separation with reunion, a single separation without reunion, repeated small doses of separation with consistent reunion with the same mother, and cumulative separations with repeated changes in mothers. It can be assumed that each of these experiences provides different learning conditions for the development of meaningful relationships. The most extreme outcome, the "affectionless character," may be the result of the most extreme conditions, i.e., repeated traumatic separations.

*Time or developmental stage at which deprivation or stress occurs.* Psychoanalytic theories regarding the significance of early experience for later development have often been interpreted as postulating that the younger the organism, the more severe and fixed the effects of an environmental impact. Only limited data are available on human subjects. Ribble (1943) tends to interpret her data on maternal rejection as supporting this point of view. Bender's and Goldfarb's (1947) retrospective studies suggest that the younger the child, the more damaging the effects of deprivation and stress. Some ani-

mal research supports this hypothesis; other studies do not (Beach & Jaynes, 1954; King, 1958).

The findings on institutionalized infants that intellectual retardation is not apparent before 3 months of age and that personality disturbances are not evident before 5 or 6 months suggest that this type of deprivation has no significant impact in the early weeks of infancy. (Because of the known unreliability of infant tests, and the lack of sensitive measures of personality and intellectual functions in early infancy, some degree of caution is necessary in interpreting these findings.)

A more refined hypothesis regarding the significance of the timing of experiences is the critical phase hypothesis which holds that there are points in the developmental cycle during which the organism may be particularly sensitive to certain kinds of events or most vulnerable to specific types of deprivation or stress. Several animal studies (Moltz, 1960; Scott, Fredericson, & Fuller, 1951; Tinbergen, 1954) support the general outlines of the critical phase hypothesis. From the assorted data on the intellectual functioning of institutionalized children a testable hypothesis emerges regarding a critical period for institutional deprivation: vulnerability to intellectual damage is greatest during the 3-12 month period. Beres and Obers (1950) suggest that institutional deprivation will differ in its impact at different developmental periods. The data on which this conclusion is based are limited. Of their four cases showing mental retardation, all were admitted to the institution under 6 months of age; the four cases developing schizophrenia entered the institution at a later age (specific age not reported).



Although the general consensus in the literature is that maternal separation which occurs before the child is 5 years of age is likely to be most damaging, the findings are not sufficiently clear to pinpoint any one age as being most vulnerable. Bowlby (1944) notes among the affectionless thieves:

in practically all these cases, the separation which appears to have been pathogenic occurred after the age of six months, and in a majority after twelve months. This suggests that there is a lower age limit, before which separations, whilst perhaps having undesirable effects, do not produce the particular results we are concerned with here—the affectionless and delinquent character (p. 41). (Quoted by permission of the *International Journal of Psycho-Analysis*.)

On the basis of our knowledge of the developmental characteristics of children, one might postulate differing vulnerabilities at different periods of development. The developmental level of the child is likely to influence the significance of deprivation or the meaning of a separation experience for him. With regard to separation, the period during which the child is in the process of consolidating a relationship with his mother may be an especially vulnerable one. Also significant may be the developmental stage with regard to memory functions. After the point in development at which the child can sustain an image of the mother in her absence and can anticipate her return, the meaning of a brief separation may be less severe than at an earlier developmental period. The degree of autonomy the child has achieved may also affect the extent of trauma experienced. The loss of the mother may represent a greater threat to the completely dependent infant than to the young child who has achieved some locomotion and some manipulatory control over his environment.

The advent of language which symbolizes even a greater degree of environmental mastery may mitigate further the severity of trauma.

Similarly, the effects of institutional deprivation may be more severe for the young infant who is completely dependent on outside sources of stimulation than for the older child who is capable of seeking out stimulation. There may also be age linked effects of different types of deprivation. Some animal studies suggest that a minimal level of stimulation may be necessary to produce the biochemical changes necessary for the development of the underlying structures. Deprivation in certain sensory modalities may be more significant at one age than at another. For example, deprivation of tactile stimulation may be most significant during the first weeks of infancy, whereas auditory or visual deprivation may become more significant later. Social deprivation may be most damaging during the earliest period of the development of social responsiveness.

*Constitutional factors.* Although the role of constitutional factors in influencing the long-term effects of early trauma has been increasingly stressed, the meager data in support of the significance of constitutional factors have been indirect. Several retrospective studies have found similar deprivation experiences in the history of individuals who in later life made satisfactory life adjustments as in those who made poor adjustments. The different outcomes are accounted for in terms of constitutional factors. In considering the role of constitutional factors a distinction might be made between organismic differences in general vulnerability to deprivation or stress and vulnerabilities in specific sensory modalities.



Data from a number of studies attest to individual differences in sensitivities in specific modalities. With regard to research design, it may be important, too, to distinguish between organismic differences which are constitutionally determined and differences in vulnerability which vary with developmental stage. While organismic sensitivities cannot be manipulated experimentally, it may be possible to study constitutional factors by developing research designs in which subjects with known differences in sensitivities are subjected to the same experimental conditions.

#### THE LONG-TERM EFFECTS: THE ISSUE OF REVERSIBILITY

It does not seem fruitful to state the question of reversibility in terms of an either-or hypothesis, i.e., whether or not early experiences produce irreversible effects. Rather the question might be: what are the conditions under which an earlier traumatic or depriving experience is likely to produce irreversible effects? The concept of irreversibility implies that an adverse experience results in permanent structural changes in the nervous system such that at some later developmental period a given response sequence is either facilitated or inhibited. A further implication is that subsequent experience plays no role in changing response potentialities or in developing responses which are incompatible with earlier established behavior patterns. Several studies suggest that permanent damage to the central nervous system may result from early sensory deprivation. Increasingly the research points to the resiliency of the organism. Beres and Obers' is one of the few investigations from the psychoanalytic orientation which makes a

strong case for the modifiability of the effects of earlier infantile experience. They cite in support a conclusion by Hartmann, Kris, and Lowenstein (1946) that

the basic structure of the personality and the basic functional interrelationship of the systems of the ego and superego are fixed to some extent by the age of six, but after this age, the child does not stop growing and developing, and growth and development modify existing structure (p. 34). (Quoted by permission of International Universities Press, Inc.)

Many factors in complex interaction undoubtedly determine the extent to which recovery is possible from early intellectual or personality damage. More pointed research is needed to identify the specific conditions under which irreversible damage to the central nervous system occurs. Also needed are specific research designs on reversibility, designs aimed at reversing intellectual or personality damage.

#### TOWARD A CONCEPT OF MATERNAL DEPRIVATION

In focusing on the isolation of simple variables for formulating testable hypotheses on the relationship between early environmental conditions and later development, we have avoided complex concepts centering around the emotional interchange between mother and infant, concepts which have been focal in psychodynamic theories. The mother as a social stimulus provides sensory stimulation to the infant through tactile, visual, and auditory media, i.e., through handling, cuddling, talking and playing with the child, as well as by simply being visually present. The mother also acts as a mediator of environmental stimuli, bringing the infant in contact with the environment and buffering or heightening the intensity of stimuli. The meaning of these mothering activities to

the child and the impact of the mother's absence varies with the child's perceptual, cognitive, and motor capacities at different developmental levels. On the simplest level, if the mother is not present, the infant may be deprived of tactile, auditory, and visual stimuli from a social source, as well as of the environmental stimuli which the mother ordinarily makes available to him. At this point, the mother's absence may be experienced by the young infant only as a deprivation of distinctive stimuli offered by a social being. The impact on the infant may be more severe if the mother's absence is accompanied by deviations in need-gratification sequences, such as, failure to have needs anticipated or long delay before gratification is provided, by marked inconsistencies in patterns of gratification, or inadequate gratification. The significance of these kinds of frustration experiences will be modified by the length of time during which they operate, the developmental level of the child, e.g., the degree of autonomy he has achieved.

The usefulness of this reduction of maternal deprivation has been demonstrated in ordering the reported research findings and in suggesting more refined hypotheses for further research. It is likely, however, that not all aspects of the mother-child relationship can be meaningfully reduced to such simple variables. We can only speculate on the process through which the mother comes to acquire special meaning to the child. We assume that the mother-image gradually evolves as a distinctive perceptual entity out of a welter of tactile, visual, auditory, and kinaesthetic cues. (There has been some speculation, without definitive data, that in early infancy before these

sensory cues are organized into a percept of an object existing outside of himself, the infant may still "recognize" the mother as an assortment of familiar stimuli.) In time through repeated contact these cues become "familiar" or distinctive to the infant, and finally there is a fixation of positive feelings on this perceptual complex. After the point of fixation of positive feelings on the mother, new elements enter into the child's reactions to a loss or a change in mothers. At this point, sensory deprivation and environmental change may be secondary, the loss of a significant person becomes of primary significance. This experience cannot occur until the infant reaches a developmental point at which he is able to conceptualize the existence of an "object" outside of himself. As a matter of conceptual clarity, it might be desirable to limit the concept of maternal deprivation to the conditions associated with the loss of a specific, cathected person, a person who has acquired distinctive significance for the child, one on whom positive feelings have been fixated.

#### CONCLUSIONS

The wide range of circumstances included under the concept of maternal deprivation stand out when the research is carefully scrutinized. Included are studies of children who have been separated from their parents and placed in institutional settings, other studies deal with children who have been grossly maltreated or rejected by their families, others are concerned with children temporarily separated from their parents because of illness, and in others the maternal functions are assumed by several different persons. These experiences have occurred at different developmental stages in the children's life

histories, and there has been considerable variation in the length of exposure to these conditions, and in the circumstances preceding and following the deviating conditions.

It is apparent that the data on maternal deprivation are based on research of varying degrees of methodological rigor. Most of the data consist of descriptive clinical findings arrived at fortuitously rather than through planned research, and frequently the findings are based on retrospective analyses which have been narrowly directed toward verification of clinical hunches.

The areas of knowledge and the areas of uncertainty become more sharply delimited when we break down the complex concept of maternal deprivation into some discrete variables. For instance, in the studies on institutional care in which sensory deprivation emerges as a major variable, we can conclude that severe sensory deprivation before one year of age, if it continues for a sufficiently long period of time, is likely to be associated with severe intellectual damage. Direct observation of children undergoing the experience of maternal separation shows a variety of immediate disturbances in behavior, permitting the simple conclusion that this is a stressful experience for children. There is no clear evidence that multiple mothering, without associated deprivation or stress, results in personality damage.

With regard to the long-term effects of early deprivation or stress associated with institutionalization or maternal separation, no simple conclusions can be drawn. In the retrospective studies, significant interacting variables are usually unknown. Longitudinal studies currently underway may offer data on the reinforcing or attenuating influence of later experiences. We might hope for more pointed longitudinal studies on questions of reversibility, such as, studies of human or animal subjects who have been subjected to experimental deprivation or trauma, or longitudinal studies of special populations chosen because of some known deviation from a cultural norm of mothering, e.g., infants who have experienced separation for adoption (Yarrow, 1955, 1956) and infants in multiple mothering situations (Pease & Gardner, 1958).

The analysis of the literature points up the need for more definitive research on the role of many "nonmaternal" variables, variables relating to the characteristics of environmental stimulation and variables dealing with organismic sensitivities. After clarification of the influence of such variables, then perhaps systematic research can come to grips with some of the more elusive aspects of the emotional interchange in the intimate dyadic relationship of mother and infant.

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## THE CURRENT STATUS OF THE SIZE-DISTANCE HYPOTHESES<sup>1</sup>

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In the history of the psychology of perception few matters have been of more continuous interest than the relationship between perceived size and perceived distance. It is our objective to examine the current status of this question by reviewing the recent literature. With some exceptions our review will be confined to investigations which have been reported since 1952. Several surveys of the literature prior to 1952 are available, and for this reason we will have relatively little to say about these earlier investigations (reviews can be found in Boring, 1942, Ch. 8; Vernon, 1954, Ch. 5; Woodworth & Schlosberg, 1954, Ch. 16).<sup>2</sup>

Most studies of this question have converged upon a single proposition which aptly has been called the Size-Distance Invariance Hypothesis. The invariance hypothesis is often stated in the following terms: "A retinal projection or visual angle of given size determines a unique ratio of apparent size to apparent distance" (Kilpatrick & Ittelson, 1953, p. 224). This proposition has been applied

repeatedly in explanations of perceived size and distance in general, and in accounts of size constancy in particular.

Two variations of this fundamental proposition also have been asserted frequently. The first may be called the Known Size-Apparent Distance Hypothesis, and it can be derived directly from the more general proposition stated above. It may be expressed as follows: an object of known physical size uniquely determines the relation of the subtended visual angle to apparent distance. This hypothesis is the basis for many explanations of size as a cue for apparent distance.

The second variation is often called Emmert's Law, and in this form has been employed in investigations of the size of the afterimage and its relationship to the distance of the projection surface. Woodworth and Schlosberg have stated the relationship in this way: "the judged size of the image is proportional to the distance" (1954, p. 486). A more general statement can be formulated also: the apparent size of an object will be proportional to distance when retinal size is constant. In this form the close relationship between this proposition and the broader Size-Distance Invariance Hypothesis is obvious. We have given the proposition independent status because it has been applied mainly to questions concerned with the perceived size of the afterimage.

For clarity of exposition we have elected to review each of these propositions separately. However, the

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<sup>2</sup> Several reviews which have appeared more recently have not added very much to the earlier treatments (see Bartley, 1958, pp. 179-187; Dember, 1960, pp. 169-192). The same can be said about the presentations contained in the recently published ophthalmological textbooks. Two illustrative discussions can be found in Bedrossian (1958, pp. 109-115) and Adler (1959, pp. 762-780).

reader will discover that on several occasions we have violated these self-imposed boundaries. In the closing section of this paper we shall present some conclusions about the size-distance relationship in general.<sup>3</sup>

#### THE SIZE-DISTANCE INVARIANCE HYPOTHESIS

This hypothesis proposes an invariant relationship between perceived size and distance such that the apparent size of an object is uniquely determined by an interaction of visual angle and apparent distance.

Support for the invariance hypothesis comes from studies which show that the size of an unfamiliar object can be judged accurately only if cues to the distance of the object are available. The prototypal experiment was performed by Holway and Boring (1941), who obtained size matches under four sets of conditions which represented a successive elimination of distance cues. Size matches approximated constancy under conditions of binocular viewing and gradually approached the law of visual angle as distance cues were eliminated. However, perfect visual angle matches were not obtained even under the condition of greatest reduction. This was attributed to a "light haze" visible within the reduction tunnel due to light reflections in

the corridor. When this cue was eliminated, perfect visual angle matches were obtained (Lichten & Lurie, 1950). These findings have been confirmed in more recent investigations which utilized a variety of stimulus objects and a variety of techniques for eliminating distance cues (e.g., Chalmers, 1952, 1953; Hastorf & Way, 1952; Renshaw, 1953; Zeigler & Leibowitz, 1957).

The results referred to above are usually interpreted as a straightforward demonstration of the dependence of perceived size on perceived distance. However, we wish to point out that the introduction of the visual angle matches as evidence for the size-distance hypothesis involves at least one of the following two assumptions: (a) under conditions of complete reduction apparent distance tends toward zero, (b) under conditions of complete reduction apparent distance assumes some value other than zero which is the same for both the standard and the variable stimulus.

The first assumption is untenable in its original form since the value "zero" distance is meaningless in the experimental contexts described earlier. Perhaps, then, "zero distance" might be interpreted to mean indeterminate distance, i.e., distance which is not regulated by specifiable cues. Still, as Woodworth and Schlosberg note, "we just do not perceive free-floating objects at unspecified distances" (1954, p. 481). Instead, the object will be localized at some specific distance. According to the invariance hypothesis, the apparent distance for any given observer (*O*), whatever it is, should interact with the visual angle to determine apparent size. However, since the reduced situation is ambiguous it is likely that apparent

<sup>3</sup> Various areas of relevant research have been omitted from this paper. Investigations dealing with the relationship between exposure time and perceived size (e.g., Allen, 1953; Comalli, 1951; Gulick & Stake, 1957; Howarth, 1951; Leibowitz, Chinetti, & Sidowsky, 1956) and the effects of relative visual direction on perceived size and distance (e.g., Gogel, 1954, 1956a, 1956b) have not been reviewed. We have also excluded reference to the developmental studies of size and distance. These investigations have been reviewed recently by Wohlwill (1960).

distance will vary for different Os. Under these conditions, the invariance hypothesis would predict corresponding variations in the size matches. This prediction, of course is quite different from the consistent visual angle matches obtained by Holway and Boring, etc. For these reasons the first assumption stated in terms of "zero" distance or "indeterminate" distance is not very convincing to us.

The assumption of equidistance seems more plausible. Carlson (1960a) and Wallach and McKenna (1960), addressing themselves to different aspects of the size-distance problem, have advanced the second assumption. Thus, Wallach and McKenna write that "the equation of image-sizes results from an implicit assumption of equal distance of the standard and the comparison object" (1960, p. 460). Carlson (1960a, p. 14) cites Gogel's (1956b) experiments as evidence for a tendency to see objects as equidistant under the conditions of the reduction experiment.

It is plain that a bias toward equidistance would explain the obtained visual angle matches. Unfortunately, there is little empirical basis for the contention that this tendency actually was operative. The experimental evidence for the equidistance tendency (Judd, 1898; Gogel, 1956b) was obtained when all of the objects in question were viewed simultaneously. In the classic Holway-Boring investigation the standard and comparison were viewed successively. Secondly, all of Gogel's experiments dealt with instances in which a monocularly viewed object was localized at the same distance as a *binocularly* viewed object. Gogel presented no evidence that the same equidistance tendency is present when all objects were viewed monocularly.

However, the Holway-Boring results were obtained when both standard and comparison were viewed monocularly. Finally, it should be noted "that the strength of the tendency for objects to appear equidistant decreases as the lateral line-of-sight separation of the objects is increased" (Gogel, 1956b, p. 16). This fact makes it highly unlikely that the equidistance tendency was effective in the Holway-Boring type of experiment.

This analysis leads us to conclude that the applicability of the visual angle data as evidence for the invariance hypothesis involves assumptions whose validity has never been demonstrated. What is needed is a systematic experimental investigation of apparent distance under varying degrees of reduction including complete elimination of distance cues. In the absence of such information the consonance of visual angle matches with the invariance hypothesis is at best conjectural.

The frequent appeals to the invariance hypothesis in explanations of perceived size have endowed this proposition with almost axiomatic status. Nonetheless, evidence has been accumulating which casts doubt on the generality of this hypothesis. In what follows we shall describe a series of investigations whose outcomes have not been consonant with the invariance hypothesis.

#### *Overestimation in Size Judgments*

A frequently confirmed finding is size overestimation which increases with distance. As the physical distance of the object is increased, the physical size of the object is progressively overestimated. While overestimation is certainly surprising, it need not necessarily be inconsistent with the invariance hypothesis. If it

should also turn out that apparent distance increases more rapidly than physical distance, then the results demonstrating increasing overestimation of size could be reconciled easily.

Let us first consider those studies which report instances of overestimation of size which increases with distance. Unless otherwise noted, the results to be described below were obtained with binocular vision and an objective matching attitude, i.e., *O* was instructed to match the standard and comparison so that they would have the same physical size. Holway and Boring (1941) found that when *O* was allowed normal binocular vision, the apparent size of a disk of light increased more rapidly with increasing physical distance than did physical size. This finding was explained as a "space error" resulting from the fact that the variable stimulus was always to the left of the standard. More recent experiments rule out this explanation. In an outdoor setting, Gibson (1947, 1950) had *O* match the size of a distant stake with the size of one of a set of nearer stakes, which stood both to the right and to the left of the more distant stake. Overestimation of the size of the distant stake increased as its distance increased from approximately 80 feet to 675 feet. The increase of estimated size with distance was greatest between 80 and 320 feet.

More recent experiments confirm Gibson's findings. Gilinsky (1955a) investigated size perception of objects presented out-of-doors at distances ranging from 100 to 4,000 feet. Size matches made under an "objective" set were greater than the physical size of the standards and increased with increasing distance of the standard. The acceleration of estimated size with distance was

greatest between 100 and 400 feet. Using somewhat shorter distances and three-dimensional stimulus objects in an outdoor setting, Smith (1953) also demonstrated that apparent size increases with distance. Under Distance Condition N, the comparison was placed at 2 feet and the standard at 16, 80, or 320 feet. Under Condition R, the comparison was placed at the remote distances and the standard nearby. As the distance of the standard was increased (Condition N) the size of the comparison had to be made progressively larger than the physical size of the standard in order to achieve apparent equality. As the distance of the comparison was increased (Condition R) it had to be made increasingly smaller in order to match the standard. At distances beyond 200 feet a comparison which was smaller than the physical size of the standard was required to produce apparent equality.

Increasing overestimation of size at distances of 20 feet and less has been demonstrated by Jenkin (1957, 1959). In his first experiment, Jenkin (1957) found that when the comparison was at 2 feet, it had to be made significantly larger than when it was at 10 feet in order to match the standard at 20 feet; i.e., apparent size increased significantly over the short distance interval from 2 to 10 feet. Since the average match at the near position exceeded the physical size of the standard, and at the far position was exceedingly close to the physical size of the standard, overestimation of size is indicated. This overestimation cannot be attributed to a space error because size judgments made with the variable at the same distance as the standard were not significantly different from the true size of the standard, while the

difference between true and judged size was highly significant when the standard was at 20 feet and the variable at 2.

In order to study more fully the relationship between small increments of distance and estimates of objective size, Jenkin (1959) performed a second and a third experiment, in which he presented comparison stimuli at distances intermediate between those employed in his earlier study. In the second experiment, the comparison was located at a distance of 20, 40, or 160 inches. In the third experiment, a fourth distance (80 inches) was inserted between the 40- and 160-inch positions. For all distances, mean size matches exceeded the physical size of the standard stimulus and became significantly larger as the comparison object was placed closer to *O*; i.e., overestimation of size increased with distance. The use of a third and fourth comparison distance made it possible to plot the results graphically. When plotted against the logarithms of the distances, the mean size matches gave points fitted by a straight line. According to Jenkin (1959), this straight line relationship "suggests the existence of some hitherto undiscovered law relating apparent size and short increments in distance" (p. 348).

In his first experiment Jenkin used natural lighting. Coules (1955) has demonstrated that a brighter object farther away appears to be at the same distance as a nearer but dimmer object (see also Ittelson, 1952). If the more distant stimulus objects in Jenkin's experiments received relatively less illumination than the nearer objects, then progressive distance overestimation might have resulted. This in turn would account for the progressive overestimation of

size which was obtained. In order to control for differences in illumination in his second experiment, Jenkin (1959) varied the illumination of the standard stimulus between 11 foot-candles and 26.5 foot-candles, while keeping the illumination of the comparison constant at 11 foot-candles. Differences in illumination of the standard had no significant effect either on amount of overestimation of size or on the rate at which it increased with distance.

In order to determine whether increasing overestimation of size would occur with a familiar stimulus object, Jenkin (1959) permitted *O* to examine the standard at a distance of 24 inches for 5 seconds before making size matches with the standard at its usual distance of 320 inches. Increased familiarity with the standard reduced the amount by which it was overestimated but did not affect the rate at which overestimation increased with distance.

In a further experiment Jenkin (1959) tested the possibility that decreasing size matches are related to decreasing ratios of distance between standard and comparison objects. This was accomplished by placing the standard 80 inch in front of *O* instead of 320 inches as formerly. If the distance ratio is crucial, then a steady decrement in the size match should be obtained from 20 to 80 inches, and an increment in the size match should be observed at 160 inches. The data of the third experiment did not confirm this expectation. The size matches decreased as the comparison receded from 80 to 160 inches.

From the experimental evidence which we have summarized, it appears that increasing overestimation of size is well-established. The invariance hypothesis demands that



increasing overestimation of size be accompanied by a tendency for apparent distance to increase more rapidly than physical distance. At least one experiment indicates that apparent distance does increase in this way: Tada (1956) performed a bisection experiment in which secondary cues to distance were eliminated. Using binocular vision, *O* made bisections by stopping one of two light spots when it appeared to be halfway between *O* and the second spot, which was fixed at a point designating the total distance to be bisected. In a second experiment, *O*'s task was to bisect a 2- or 4-meter interval, presented at various distances from *O*, with each of its end points marked by a bright spot. In both experiments, Tada found that the phenomenal midpoint was farther than the objective one. In other words, the farther half of the distance was overestimated as compared with the nearer half.

Tada's findings are given some support by Purdy and Gibson (1955). They found that when *O* was permitted full primary and secondary cues to distance, errors in dividing distances (up to 300 yards) into halves and thirds tended most frequently to involve making the nearer segment too large in comparison with the farther. However, few errors were made; in general, perceived magnitudes of distance corresponded well with physical magnitudes of distance. Consistent findings of a large acceleration of apparent size with distance would seem to demand a reasonably large and consistent tendency to overestimate the farther distance as compared with the nearer.

The invariance hypothesis is further weakened by the fact that at least two experiments on distance estimation give results exactly opposite to those of Tada (1956).

Gilinsky (1951) has presented evidence which indicates that perceived distance increases with true distance at a *diminishing* rate. The experimenter (*E*) moved a pointer at a slow and nearly constant rate along the ground away from *O*, who instructed *E* to mark off successive increments of equal perceived length. In the case of one *O*, every increment of apparent distance represented an attempt to match a memorized "subjective foot rule"; in the case of the other *O*, a memorized "subjective meter stick" was being matched. For both *O*s apparent distance increased more slowly than physical distance. This experiment is defective because error in bisection experiments is related to the direction of motion of the pointer; as the pointer withdraws, *O* tends to make the farther segment too large in comparison with the nearer (Purdy & Gibson, 1955). This defect was avoided in a second experiment by Gilinsky (1951). Across a large, flat lawn, a line was stretched perpendicular to the frontal, parallel plane of *O*. *O* was required to bisect each one of 14 distances, ranging from 8 to 200 feet, by stopping a pointer, which moved back and forth along the line, at a point which appeared to be halfway between the near end of the line and a marker indicating the total distance to be bisected. The results were the same as in the previous experiment.

Smith (1958) also found that far distances tend to be underestimated in comparison with near ones. As a standard stimulus he used a white sheet of oilcloth, which was spread out on the floor of a hall. The variable stimulus was a strip of the same oilcloth rolled from a small roller. To match the length of the standard, the variable was made 15.1% longer than the standard.

The invariance hypothesis must be



abandoned if we accept both the finding of apparent distance which increases less rapidly than physical distance and the finding of increasing overestimation of size. A way out of this difficulty is suggested by Carlson (1960b), who maintains that increasing overestimation of size is an artifact of "objective" instructions. When *O* is trying to judge actual, physical size, his size matches will be influenced by his beliefs about size-distance relationships. The major attitude by which *O* will be influenced is the concept of perspective—the notion that apparent size becomes smaller as distance increases. "From *O*'s point of view, a near object must 'look' larger than a far object for the two to be equal in physical size" (Carlson, 1960b, p. 200). Hence *O* will make size matches which appear to indicate an overestimation of the far object.

Given several discriminably different distances in the same setting, amount of overestimation may be a fairly precise function of distance, but only because trials at different distances are not really independent, and *O* can judge the distances relative to each other (p. 201).

In support of his thesis, Carlson (1960b) pointed out that overestimation does not occur in experiments, such as those of Brunswik (1956, pp. 67–69) and Singer (1952), in which *O* is asked to base his size judgments upon a naive, natural impression of size ("look" instructions). Carlson (1960b) performed an experiment in which *O* was allowed, but not required to differentiate apparent visual size from objective size. Using free binocular regard, *O* adjusted a 10-foot distant variable triangle to match a 40-foot distant standard. *O* was also required to bisect the distance to the apparatus on which the standard triangle had been presented. Under apparent size instructions, size

matches were accurate. Under objective size instructions, overestimation of size occurred. We are told that under both "look" and "objective" instructions, "the half-distance of the standard was . . . overestimated" (p. 206). Apparently this means that *O*, in bisecting the distance to the standard's apparatus, required the marker to be placed too close to himself. If so, the results indicate that apparent distance increases less rapidly than physical distance.

It is doubtful that Carlson has removed the difficulties facing the invariance hypothesis. Carlson (1960b) used only one pair of distances; if either the standard or the variable had been placed at more than one distance, he might have found that estimated size increases with distance under "look" instructions, even though overestimation does not occur. The published data of Brunswik (1956, pp. 67–69) and of Singer (1952) do not provide an answer to this question. Furthermore, Carlson's finding that size is accurately estimated does not match his finding that apparent distance increases less rapidly than physical distance.

Instead of linearly increasing overestimation of size, some investigators have reported a curvilinear relationship between physical distance and overestimation of size. Hastorf and Way (1952) found that when distance cues are available, overestimation of size increases from 10 to 20 feet and decreases from 20 to 30 feet. Chalmers (1952) found that overestimation increased from 10 to 20 feet and decreased from 20 to 50 feet when *O* viewed the 10-foot comparison binocularly.

It should be noted that even if the reported instances of progressive overestimation of size should be accounted for by progressive overesti-

mation of distance this would still leave unexplained the curvilinear size distance relationship obtained by several investigators.

### *Nonmatching Judgments of Size and Distance*

According to the invariance hypothesis, the perceived size of an object is proportional to its perceived distance, when its retinal image size is held constant. This requirement of proportionality is frequently not met when size and distance judgments are both made in the same experimental setting. For purposes of exposition, we may divide the experiments which produce nonproportional results into two classes: (a) In the first class are included those experiments which provide evidence for a "size-distance paradox"—a consistent tendency either to couple an underestimation of the relative size of an object with an overestimation of its relative distance or to couple an overestimation of the relative size of an object with an underestimation of its relative distance. (b) In the second class are those experiments which show that a variable having a consistent influence on size judgments has no consistent influence on distance judgments, and, correlatively, those experiments which show that a variable having a consistent influence on distance judgments has no consistent influence on size judgments.

*Class 1: The Size-Distance Paradox.* A striking example of the size-distance paradox is the moon illusion. As is well known, the moon appears larger on the horizon than at the zenith. According to the invariance hypothesis, it should also look farther away. Yet *O* usually reports that the moon looks closer when it is low in the sky. The most recent discussion of this time honored problem is by Kaufman and Rock (1960).

More detailed evidence for the size-distance paradox is provided in an experiment by Gruber (1954). The standard stimulus was a triangle which was alternately 10 and 15 centimeters in height. To the right of the standard was a variably sized triangle. This variable triangle was placed at six distances ranging from 200 to 450 centimeters. For each distance *O* made four kinds of judgments, all of them under "look" instructions:

1. *O* set the variable-size triangle so that it appeared equal in size to the standard (a) when the standard was half as far from *O* as the variable, and (b) when both stimulus objects were equidistant from *O*.

2. *O* adjusted the distance of the standard so that it appeared (a) half as distant as the variable, and (b) equidistant with the variable.

The results were all contradictory to the invariance hypothesis:

1. By setting the size of the variable significantly larger than the actual size of the standard in the size constancy matches (judgments of Type 1a), *O*s exhibited a mean *overestimation* of the relative size of the standard. However, a mean *underestimation* of the relative distance of the standard occurred; *O* set the standard sized triangle too far away in the half-distance judgments.

2. "Analysis of individual differences revealed no correlation between size and distance judgments." (Gruber. 1954, p. 426).

3. As the physical distance of the farther object increased, the mean constant error in size constancy matches rose from 4% to 23%, whereas the mean constant error in half-distance judgments did not vary progressively with absolute distance, fluctuating around 17%.

4. The mean errors in the control judgments (1b and 2b) were not large enough to account for the magnitude of the errors in the size

constancy and half-distance judgments.

By means of her size-distance equations, Gilinsky (1955b) attempted to show that Gruber's data are properly interpreted as supporting rather than rejecting the hypothesis that perceived size is proportional to perceived distance. However, Gruber (1956) has pointed out that Gilinsky's analysis does not apply to his most interesting result, the Finding 1 above that an object which is consistently overestimated in size is consistently underestimated in distance. Gilinsky's analysis deals only with Finding 3, and in order to do so, it must make use of a number of somewhat arbitrary assumptions.

Jenkin and Hyman (1959) report that when *O*s are given an "objective" set, Gruber's finding of a size-distance paradox is confirmed. Size judgments were obtained under four different distance conditions: (a) comparison 30 feet and standard 15 feet from *O*, (b) comparison 30 feet and standard 2 feet from *O*, (c) comparison 15 feet and standard 1 foot from *O*, and (d) comparison 15 feet and standard 15 feet from *O*. *O* made size judgments under two different instructions: to match for physical size, and to match for retinal image size. Following the size judgments, the black mounting-board upon which the variable had appeared was placed 30 feet from *O*, who was required to make estimates (in feet) of this distance. Under objective instructions, *O*s either judged the variable as relatively small and its mounting as relatively remote, or as relatively large and its mounting as relatively near.

The relationship of analytic size-judgments to estimated distance was toward the distant object being regarded as relatively large and relatively remote, or relatively small and relatively near (p. 73).

Thus we have the paradoxical result that an *O* who is set to judge physical size responds as if he were ignoring the simple geometrical help which would come from taking distance into account, while a person who is deliberately trying to ignore distance in order to get retinal image matches responds as if he were taking distance into account. Assuming that the analytic judgments represented *O*'s best attempt to respond in terms of retinal image size, and assuming that objective size judgments represent perceived size, the invariance hypothesis demands, for any given distance, a positive correlation between analytic size judgments and objective size judgments. Such a correlation was not found.

Heinemann, Tulving, and Nachmias (1959) obtained nonmatching size and distance judgments in an experimental situation in which *O* was permitted only primary, monocular cues to distance. When distance judgments were being made, the comparison was held constant at 1° and *O* reported which of two successively presented disks, standard or comparison, was farther away. When judging the relative distance of a standard and a variable, most *O*s said that the objectively nearer disk was farther away. Since the far object looked nearer than the near object (which subtended the same retinal angle), it should have been judged as smaller than the near object, if the invariance hypothesis is true. Yet size matches were consistently "in the direction of size constancy"; the farther away an object was, the larger it was judged as being.

Kilpatrick and Ittelson (1953) have drawn attention to two phenomena of accommodation which involve a size-distance paradox. They cite Aubert's finding that

partial paralysis of accommodation produces both a reduction in the apparent size of an object and an increase in its apparent distance. They also report von Kries' observation that an object appears to diminish in size and also to recede when *O* shifts fixation from that object to one closer by. However, both these findings are complicated by the fact that changes in accommodation involve changes in retinal image size (e.g., Pascal, 1952).

*Nonproportional Results of Class 2.* A number of studies indicate that when visual angle is constant, changes in apparent size are not consistently accompanied by changes in apparent distance, and changes in apparent distance are not consistently accompanied by changes in apparent size. Beginning with the classic experiments of Wheatstone and Judd, it has been frequently found that increases in convergence are regularly accompanied by decreases in apparent size. Insofar as the decrease in retinal image size accompanying convergent accommodation is not sufficient to account for the obtained decrease in apparent size, the invariance hypothesis requires that the decrease in apparent size be accompanied by a decrease in apparent distance. Yet the obtained changes in apparent distance are equivocal. This result was corroborated recently by Hermans (1954), who used a telestereoscope to produce six changes in convergence from 0 to 10°. As degree of convergence increased, the mean apparent size of the standard, as determined by *O*'s adjustment of a variable, decreased significantly. Verbal reports indicated that some *O*s perceived a decrease in distance with increasing convergence, while other *O*s perceived an increase in distance.

Kilpatrick and Ittelson (1953) found that an illusory movement in depth was not accompanied by the required change in apparent size. The trapezoidal window was suspended in *O*'s line of sight, so that its sides were vertical and the physically larger end of the trapezoid was farther from *O* than the smaller end. An ordinary playing card and a piece of cotton were successively moved through an opening in the window by means of a thread stretched at right angles to the line of sight. Objects carried through the trapezoid in a straight path by the moving thread appear to move through an S shaped path in the horizontal plane. In the majority of observation trials, *O*s perceived definite movement in depth of 2 feet. Yet for the largest number of trials on which movement in depth was perceived, no size changes were reported either for the playing card or for the cotton. On the remaining trials on which movement in depth was reported, size changes in a direction opposite to that required by the invariance hypothesis were reported about half as frequently as changes in the required direction. In a second experiment, an ordinary sized playing card was suspended from each of the two stationary wires by means of which the trapezoid was hung from the ceiling. On 19 trials *O*s perceived one card to be larger than the other. But on only 10 of these 19 trials did *O*s perceive the apparently larger card to be farther away, as required by the invariance hypothesis.

According to the invariance hypothesis, an improvement in *O*'s ability to estimate the distance of an unfamiliar object should result in an improvement in his ability to estimate its size. Using a series of photographs of the Gibson size-at-a-distance set-up (described above), Gib-

son and Smith (1952) found that training in estimation of the distances of the stakes in the photographs significantly improved *O*'s accuracy in estimating these distances. However, there was no significant improvement in *O*'s ability to estimate the sizes of the stakes.

Another finding contrary to the invariance hypothesis involves the visual tau effect (cf. Geldreich, 1934). Kilpatrick and Ittelson (1953) note that the difference in the perceived lateral separation of the points is not accompanied by any change in the apparent distance of the pairs of points from *O*.

*Matching Judgments of Size and Distance.* We have seen that most experiments which obtain size and distance judgments in the same setting provide evidence against the invariance hypothesis. However, in two experiments in which convergence provided the chief distance cue, matching size and distance judgments were obtained.

Bleything (1957) used a stereoprojector to cast two ring targets onto a screen. Observer and projector were equipped with polaroid filters making it possible for one ring to be seen with one eye only and the other ring to be seen with the other eye only. *O* saw a single fused ring which appeared to approach and recede in depth as *E* varied the distance between the center of the projected rings. As required by the invariance hypothesis, the apparent size of the fused ring increased with apparent distance, although the perceived size of the ring increased at a slightly greater rate than predicted by the formula,  $s = (a)(d)$ .

Roelofs and Zeeman (1957) report that when retinal image size is constant, a number of variables which affect apparent size also produce a

complementary change in apparent distance. Two series of figures were presented. In the first series each card bore six figures: two pairs of equal sized circles which were fused binocularly (orthoptically) to give two perceived circles, and two circles which were presented either to the right or left eye alone. For the first series, Roelofs and Zeeman report the following findings:

1. Of the two circles seen binocularly, the one which required the greater convergence always appeared smaller. As required by the invariance hypothesis, it also always appeared closer to *O*.

2. The apparent size of the circles seen monocularly tended to be intermediate between the apparent sizes of the two circles seen binocularly. Matching this, the apparent distance of the monocularly seen circles tended to be intermediate between the apparent distances of the binocularly seen circles.

3. For a given card, the apparent size of a monocularly seen circle was closer to the apparent size of the binocularly seen circle from which it had the smallest physical separation on the card. As required, the apparent distance of the monocularly seen circle was also closer to the apparent distance of the nearby, binocularly seen circle.

4. The apparent size of the circles seen monocularly was just as strongly influenced by the circles seen binocularly with a weaker convergence as by the circles seen binocularly with a stronger convergence. However, the apparent distance was more strongly influenced by the circles seen with a stronger convergence. This is the only general finding of Roelofs and Zeeman which contradicts the invariance hypothesis.

5. Monocularly seen circles in the



lower half of the stimulus card tended to be perceived as smaller than and, matching this, as nearer than monocularly seen circles in the upper half of the card.

6. Monocularly seen circles in the nasal position tended to be seen as smaller than and as closer than monocularly seen circles in the temporal position.

7. Monocularly seen circles in the left half of the optic field tended to be seen as smaller than and as closer than monocularly seen circles in the right half of the field.

The second series of stimulus cards used by Roelofs and Zeeman had three equal sized circles: a single circle which was presented to one eye only and a pair of circles which were fused binocularly to give a single perceived circle. For the second series, the apparent size of the circles seen binocularly was greater than the apparent size of the circles seen monocularly. Matching this, the apparent distance of the binocular circles was greater than the apparent distance of the monocular circles. The findings obtained with the earlier stimulus series were corroborated with respect to the effects on apparent size and distance of nasal vs. temporal, right vs. left, and higher vs. lower stimulus positions.

Although the general findings of Roelofs and Zeeman are in accord with the invariance hypothesis, there were some individual exceptions to the required matching of size and distance judgments for all findings except the first.

In at least one respect, the experiments of Bleything (1957) and of Roelofs and Zeeman (1957) provide a fairer test of the invariance hypothesis than do the experiments which produce nonmatching judgments.

Bleything, and Roelofs and Zeeman had *O* estimate the size and distance of the stimulus almost *simultaneously*. In the other experiments a relatively long temporal interval separated the estimations. It is possible that when *O* is asked to make adjustments of size (distance), his perception of size (distance) occupies the center of attention, and his perception of distance (size) is relegated to the background. The perception of both size and distance when they are merely registered as background may differ from their perception when they occupy the observer's close attention. Hence, when *O* is set to perceive size and distance at the same time, it is more likely that his judgments will match as required by the invariance hypothesis than when he is set to perceive only size or distance and not both.

Despite the methodological reservations mentioned immediately above there is sufficient cause for concluding that all is not well with the traditional formulation of the size-distance relationship. It remains to be seen whether the generally accepted invariance hypothesis can by any means be reconciled with the contradictory findings described in this section. In the eventuality that this reconciliation will prove impossible, then the way is open for a restatement of the size-distance relationship. It is also possible that in certain instances size and distance perception are unrelated. Despite their temporal co-occurrence these two experiences may be independent but simultaneous responses to separate aspects of the proximal stimulus situation. Some experimental evidence that this may indeed be the case has been presented by Gruber (1954) and Epstein (in press).



### THE KNOWN SIZE-APPARENT DISTANCE HYPOTHESIS

According to this hypothesis the known size of a stimulus object determines a unique relation of retinal image size to apparent distance. Two corollaries can be derived easily from this proposition:

Corollary 1. Discrete changes in the size of the retinal image of an object whose known size remains constant will be perceived as corresponding changes in the apparent distance of that object.

Every identified object may be said to possess an "assumed size." This term refers to "the entirely subjective sense of size which the observer might relate to a specifically characterized physiological stimulus-pattern" (Hastorf, 1950, p. 195). The second corollary deals with assumed size.

Corollary 2. Changes in the assumed size of an object whose retinal size remains constant will result in appropriate changes in the apparent distance of that object.

#### *Corollary 1*

Most of the investigations which have been reported are concerned with Corollary 1. An ingenious experimental test of this proposition which has been cited often was performed by Ittelson (1951). In one experiment three playing cards were presented singly to *O* under conditions of complete reduction. Each of the cards was placed at the same physical distance from *O*. The task for *O* was to adjust a comparison stimulus of familiar size, which was presented separately, until the comparison object and the standard playing card appeared to be at the same distance. The neat turn in this experiment concerns the sizes of the

three cards: one was a normal sized card, all the dimensions of another one were doubled, and the dimensions of the third card were halved. Presumably, in this situation, the only cue available for the estimation of distance was retinal size which varies directly with changes in physical size when distance is constant. When known size is invariant, these changes in retinal size ought to be perceived as changes in distance and not as changes in size. The larger card should be localized at a point half way between *O* and the distance at which the normal card is perceived, and the smaller card should be localized at twice the distance of the normal card. The results for five *O*'s confirmed these expectations almost exactly (Ittelson, 1951, p. 64).

This experiment has been vigorously criticized by Hochberg and Hochberg (1952) who have argued that Ittelson and others have failed to distinguish between familiar size, on the one hand, and the *relative* size of the stimuli on the other (i.e., change or difference in size of objects of similar shapes). For this reason, Hochberg and Hochberg (1952) designed an experiment in which familiar size and relative size were separated. Two figures were drawn on a two-dimensional, reversible screen drawing. One panel contained a drawing of a man, and on the other panel a boy of the same size and approximate contour was represented. The question is whether the panel with the boy appears to be nearer more often than the panel containing the man. This is to be expected if familiar size is determining apparent localization. The results showed that familiar size was ineffective in this situation.

In a second experiment the effec-

tiveness of *relative* size was tested. The same procedure was followed with one difference. Whereas the first experiment held relative size constant while familiar size was varied, the second experiment held familiar size constant while varying relative size. Both panels contained drawings of the same boy, but one was a reduced version of the other. Here, relative size would lead to localizing the panel containing the larger boy nearer than the other panel. The results were in agreement with this expectation. These findings led the authors to suggest that there may be a stimulus bound correlation between retinal size and perceived distance which would make the introduction of unconscious assumptions (about known size) unnecessary.

Further experimental evidence in support of this emphasis on relative size is presented by Hochberg and McAlister (1955). Four cards, each bearing one small figure and one large figure were presented singly. Card 1 bore a large circle and a small circle; Card 2, a large square and a small square; Card 3, a large circle and a small square; and Card 4, a large square and a small circle. In terms of relative size, it would be expected that Cards 1 and 2 should yield more three-dimensional responses than Cards 3 or 4. This was the case.

In a second experiment the authors inquired whether the direction of the three-dimensional responses is in accordance with what would be predicted in terms of relative size.

In terms of the cue of relative size the larger figure should appear nearer than the small one in Cards 1 and 2. They did. If this were due to the operation of familiar size, we would expect similar results to hold with respect to Cards 3 and 4 (p. 296).

This did not happen.

Ittelson (1953) has replied to the

above criticisms by citing several instances in which relative size is not involved. These are cases when only a *single* object is present in the field. Ittelson argues that if a single, familiar object viewed monocularly in a dark room is replaced by another of the same physical size, but of different assumed size, the apparent distance of the second will be different from the first. The clearest demonstrations of this effect have been Ames' "watch-card-magazine" experiment (1946-47) and Hastorf's similar investigations (1950). We will describe Hastorf's study later in this section when we consider Corollary 2.

In addition Ittelson (1953) maintains that if a single, familiar object is viewed monocularly in a dark room, it is perceived immediately and unequivocally at some definite distance which can be correctly predicted on the basis of the familiar size of the object. Finally, the claim is made that the size-distance perceptions related to a given stimulus can be changed by immediately prior experiences which change the size which is attributed to the stimulus. As an illustration Ittelson cites the experiments which demonstrate the influence of size assumptions on perceived radial motion (see Kilpatrick & Ittelson, 1951).

The latter two assertions are incompatible with an explanation based on the relative size cue. However, subsequent investigations have failed to confirm their validity, and have provided further support for the relative size thesis (also see Hochberg & Hochberg's—1953—rejoinder to Ittelson). The experiments reported by Gogel, Hartman, and Harker (1957) show that the retinal size of a familiar object is totally inadequate as a cue for the *absolute* apparent distance of that object. The investigations re-

ported by Epstein (in press) confirm the findings of Gogel et al. and also demonstrate that experiences which modify *O*s assumptions concerning object size do not modify his perceptual experience. The problem for Gogel et al. (1957) was to "investigate whether the retinal subtense of a familiar object can act as a determiner of the apparent *absolute* distance of that object from the observer" (p. 1). This study employed a nonvisual method of measuring perceived distance of the object. *O* was asked to throw a dart to the perceived distance without seeing the results of the throw. Since successive throws might involve relative distance judgment, only the response to the object which was *first* perceived was considered in measuring the perceived absolute distance of that object. The stimulus object was a normal or double sized playing card, located at a distance of 10 or 20 feet in a reduced cue situation.

The distance responses for the stimuli initially presented did not confirm the expectations which follow from the Known Size-Apparent Distance Hypothesis. Not only did the results fail to agree with any precise predictions of apparent localization, e.g., the double sized card at a physical distance of 20 feet should be localized at 10 feet, but the less stringent prediction, e.g., the double sized card should appear to be nearer than the normal card, was also not confirmed. Under these conditions perceived distance was totally unrelated to retinal size.

When a similar analysis was performed for all of the four reduced cue situations collectively (i.e., the *same* *O*s in all four situations), partial support was obtained for the Known Size-Apparent Distance Hypothesis in its less precise formulation. The implication of this finding is clear.

The secondary analysis shows only that *relative* distance perception, as some function of *relative* retinal subtense, can occur for successively presented stimuli.

The first of three experiments reported by Epstein (in press) was essentially a replication of Ittelson's (1951) experiment with two major modifications: (a) prior to the judgmental task *O*s in the Experimental Group participated in a card game which was designed to modify their assumption concerning the normal size of cards, and the constancy of the physical size of cards, (b) at the conclusion of the distance settings all *O*s were required to judge the apparent size of the stimuli.

The results of this experiment did not support the known size hypothesis. Despite the modifying treatment experienced by the Experimental Group there was no difference between the distance judgments of the Experimental Group and a Control Group which did not have prior training. In addition, none of the distance judgments met the precise quantitative requirements of the known size thesis, e.g., while the quarter sized card appeared to be more distantly located than the normal card, it was *not* set at four times the distance of the normal card. Finally, the stimuli of different physical size were also judged to be of different size.

In Experiment II it was demonstrated that similar apparent distance effects would obtain when only relative retinal size is operative (known size and assumed constancy of physical size absent). Finally, in Experiment III it was shown that in the absence of the relative size cue no systematic size-distance effects are obtained. The results of Experiments II and III bolster the position adopted by Hochberg and Gogel.

In this connection the results re-

ported by Gogel and Harker (1955) may also be cited. Gogel and Harker obtained judgments of apparent distance for two playing cards of different sizes under reduced cue and near complete cue conditions. They found that the relative apparent depth of the two cards was a function of the lateral separation between the two cards. They concluded that "the effectiveness of size cues to relative depth increased as the lateral separation of the differently sized cards was increased" (p. 315). There is no reason to expect such results if the original depth effects were based on the operation of an assumed size factor.

This review leads to the conclusion that despite its reasonableness Corollary 1 of the Known Size-Apparent Distance Hypothesis is unnecessary. Many of the experimental effects which are most frequently cited as evidence for its validity are more simply attributed to other factors, e.g., relative size. In those cases in which these factors are eliminated the "Known Size Effect" is also eliminated. The question remains whether all reported effects of known size on apparent localization can be explained in this way. This brings us to Corollary 2 of the Known Size-Apparent Distance Hypothesis.

#### Corollary 2

The second corollary requires that a *single* object whose physical size remains unaltered will undergo changes in apparent spatial localization with changes in the physical size which *O* attributes to the object. Thus, if the same object is assumed by *O* to have a small size at one time, and a large assumed size at a later time, it will be perceived to be more distant at this later time although the physical distance of the object is the same at both times. It is obvious

that effects of this nature cannot be accounted for by processes which depend on the opportunity for comparisons of successively presented stimuli which differ along a physical dimension.

There are very few experimental studies which demonstrate that such an effect does indeed obtain. In Hastorf's (1950) investigations a rectangular or circular area of light was given a "large assumed size meaning" or a "small assumed size meaning." That is, the rectangle was called either an envelope or a calling card, and the circle was called either a billiard ball or a ping-pong ball. The size at which the stimulus was set, in order to appear at a specific distance, varied when the assumed size attributed to the stimulus was varied by the size suggestion, i.e., by naming the stimulus.

In a study of the effects of past experience on apparent size, Smith (1952) reported findings which may be interpreted in the same way. In the first stage of the experiment *O* judged the apparent distance of several simple geometrical forms, e.g., circles and squares. Then, over a period of 2.5 weeks *O*s participated in a series of tasks requiring the manipulation and discrimination of geometrical forms of the same shape but larger in size. In this way *E* hoped to alter the attributed size of the original forms. Then the *O*s were retested, i.e., *O*s repeated the judgments which were made prior to training. The distance judgments were observed to change in the direction demanded by the modification in attributed size.

Finally some incidental findings of Ittelson (1951) may be mentioned. In one variation of the experiment described earlier *O* judged the apparent distance of a half sized playing card and a matchbox of identical size

when both were located at the same objective distance of 7.5 feet. The playing card was localized at a distance of 14.99 feet while the matchbox was judged to be at a distance of 8.96 feet. Apparent distance was influenced by *O*'s assumptions concerning the physical size of the stimulus objects.

Corollary 2 has received support from the investigations described above. Still, there is clearly a need for further experimentation. In particular it would be useful to have the results of experiments which meet the following three requirements:

1. A measure of *O*'s *immediate* perceptual impression should be obtained. In most cases *O* has been allowed an extended period of time in which to make an adjustment which he is "satisfied with." Under such conditions many judgmental and attitudinal factors may enter into the adjustment process, and contaminate or at least alter the identity of the effect.

2. Different *O*s should be used for the various attributed size conditions. It is possible that the same *O* performing under the various conditions may be making memorial comparisons between the first attributed size-apparent distance judgment and the requirements of the current situation. This possibility is minimized if an extended temporal interval intervenes between the required judgments. Nonetheless, even though 6 days intervened between successive critical judgments in Hastorf's experiments, Hastorf (1950) reports that "some subjects did appreciate the fact that it was the same stimulus objects being given two different names" (p. 208).

3. In addition to these two requirements it might be helpful to obtain a measure of apparent size independently of *O*'s distance judgments. The

results of earlier experiments suggest that such information may be instructive.

#### THE RELATIONSHIP BETWEEN THE SIZE OF THE AFTERIMAGE AND DISTANCE

A special case of invariance is Emmert's Law. The law states that the size of a projected afterimage (AI) is directly proportional to the distance from the eye to the projection surface. This statement follows from simple geometric considerations if we keep in mind that for the case of AIs the subtended visual angle remains constant regardless of variations in projection distance. The apparent simplicity disappeared following Boring's (1940) well-known attempt to demonstrate that Emmert's Law implies its converse, size constancy. Boring's thesis has been expressed succinctly by Edwards (1950):

What Boring was saying was that apparent size must increase with constant retinal size and increasing distance, if it is also true that apparent size remains constant with shrinking retinal size and increasing distance (p. 611).

We will not review the logic of Boring's formulations. It will suffice to point out that these formulations hinge on Boring's substitution of apparent size for physical size in the optical geometry of Emmert's Law. This substitution has been strongly criticized by Young (1950). Nevertheless, Boring's thesis has stimulated the major portion of writings concerned with Emmert's Law in the last 10 years. This work has followed two main themes.

#### *The Historical Issue*

Young (1950, 1951) has contended that Emmert intended to deal only with nonpsychological, Euclidian optical relationships. The contention is that Emmert's original reference (1881) was to the physical size of the



AI as determined by direct physical measurement of the occluded area on the projection surface. Young also maintains that a fundamental difference exists between real objects and AIs, and that it is inappropriate to speak of the apparent size of the latter.

The opposing view holds that Emmert was either concerned directly with apparent size and had, himself, implicitly made the substitution of  $s$  for  $p$  for the special case of AIs (Edwards, 1950), or that he did not distinguish the two different meanings of size perception (Boring & Edwards, 1951). The determination of apparent size requires a comparative technique. This method usually takes the form of judging the size of the critical object on the basis of an adjustable comparison stimulus or a series of different sized stimuli. These, generally, are separated both in the lateral and frontal plane from the critical object. This method has found wide application in research on size constancy where apparent size is the crucial dimension.

Despite a careful reading of Emmert's original article (1884) there is little that we can contribute toward a resolution of this historical issue.<sup>4</sup> The one experiment which Emmert described in detail did utilize comparative stimuli, but both were attached directly to the projection surface. We are inclined to agree with Boring and Edwards (1951) that Emmert, in his own research, was not making a clear distinction between physical and apparent size.

### *The Theoretical Issue*

The second aspect of the controversy is of greater significance. If

<sup>4</sup> We are indebted to Martin Scheerer of the Department of Psychology of the University of Kansas for his expert translation of Emmert's article.

Emmert's Law and size constancy are derivable from the same processes, then those conditions which determine the perceived size of real objects should affect the size of the AI also. If communality of process is not the case then the size of the AI should be unaffected by the same variables which affect the perceived size of real objects (or at least the effects should not be identical).

Edwards (1950) suggested that an experimental decision on this matter depends in part on the selection of an appropriate method of measurement.  $E$  can adopt either of two methods: (a) indirect measurement by employing a comparison stimulus or (b) direct measurement on the plane of projection. Edwards predicted that under reduced cue conditions Emmert's Law would fail when measured by Method *a* (i.e., the size of the AI would remain constant with increasing distance) but would hold when measured by Method *b*. Much of Edwards' position had been stated earlier by Helson (1936). In this paper Helson interpreted his results as showing that:

when cues to distance and surroundings are eliminated the apparent size remains practically constant while the measured size of the projected image tends to obey Emmert's Law (p. 638).

Edwards (1953) tested one aspect of this prediction, viz., that the apparent size of the AI when measured by the comparison method would not conform to Emmert's Law under reduced cue conditions. Os projected AIs monocularly on to a dimly illuminated screen while looking through a reduction tube. The distance of the projection screen varied in five steps from 42 to 90 inches. A 2-inch luminous square in the same reduced field was adjusted until it appeared equal in size to the AI. No significant differences between the various dis-



tances were obtained. Edwards concluded that Emmert's Law (i.e., "Emmert's Law of Apparent Size") had failed under reduction conditions. However, as Edwards himself admits, it is somewhat tenuous to uphold a prediction on the basis of confirmation of the null hypothesis.

Hastorf and Kennedy (1957) also contend that the controversy concerning the relationship of Emmert's Law to size constancy is primarily a matter of the type of measurement used. Under reduction and nonreduction conditions *O*s judged the size the real objects and AIs at various distances by the comparison method and the direct method (bracketing spotlights). The results for the comparison method confirmed Edwards' position, i.e., in the reduced cue situation, size constancy was greatly decreased and Emmert's Law did not obtain. With direct measurement there was no significant difference in the size of the AI between the reduced and full cue situations. This outcome supports Young's position. Thus, both sides of the controversy received support as did the authors' contention that the controversy hinges on different measurement techniques. However, Hastorf and Kennedy also reported that the use of bracketing spotlights in a dark room might provide a distance cue. If this is true, then it must be concluded that the direct measurement of the physical size of the AI under authentic reduction conditions remains to be accomplished.

Crookes (1959) takes a somewhat different approach to the problem of measurement. Crookes agrees with Young (1950, 1951) that Emmert's Law concerns "real," not apparent size. Further, he proposes that if Borring (1940) is right, Emmert's Law and size constancy should hold equally well when apparent size matches are

obtained under the same conditions. Using the comparison method under "analytical" instructions, i.e., stressing retinal size, *O*s matched AIs and real objects. Crookes found that *O* made significantly better matches (i.e., showed significantly more constancy) in the case of the real objects. Crookes concludes that the subsumption of Emmert's Law and size constancy under a common heading is not justified. However, the objection could be raised that the analytical attitude induced by the instructions does not suit the purposes of research on constancy phenomena. Also, there is some question whether the greater constancy in the case of the real objects might not be due to the relatively greater ease of viewing real objects.

These studies concerned with the relationship between Emmert's Law and size constancy are not unanimous in their conclusions. Nevertheless, it is generally conceded that the method of measuring the AI may be critical. Thus, we might expect two or more forms of Emmert's Law to emerge, each embodying its own mode of measurement and each bearing a different relationship to other size-distance phenomena.

New approaches to measurement should be tried in this context, especially those promising some increase in precision. For example, Onizawa (1954) has developed a method whereby a screen bearing a comparison stimulus moves away from *O*, while a projection screen bearing an AI moves toward *O*. When *O* perceives equality between the AI and the comparison stimulus, he stops this movement. Ratios based on the respective distances of the two screens from *O* are compared with like ratios predicted from Emmert's Law. Onizawa presents data which indicate that his technique incurs less vari-

ability than the method of directly measuring the AI on the projection surface.

However, before the role of different measures can be clearly evaluated it will be necessary to test them together under identical conditions (e.g., reduction conditions). This requires that a given measure must not, itself, disqualify such conditions. Hastorf and Kennedy's (1957) observation (i.e., spotlights provide distance cues under reduced conditions) illustrates this problem.

Another matter deserving comment is related to the hybrid nature of Boring's formulation. While Boring has substituted apparent size for real size he has not seen fit to substitute apparent distance for physical distance. A careful reading of Boring's discussion (1942, p. 292) reveals a confusion of physical distance with apparent distance. The two terms are used interchangeably, seemingly without regard for any differences which may exist. It would be interesting to obtain pairings of the apparent size of the AI with the apparent distance of the projection surface. Such relationships if found to conform to Emmert's Law could hardly be explained in terms of the requirements of Euclidian geometry which applies only to physical distances and extents.

In this regard an additional complicating factor has been described by Ohwaki (1955). While expected values of Emmert's Law have been based on retinal size arising from the physical size and distance of the fixation object, Ohwaki (1955) found that perceived, not physical, distance was crucial in determining retinal size. Perceived distance was effective with either ordinary distance cues or past experience available. The interpretation was offered that it is perceived distance which underlies accommoda-

tion. Accommodation in turn regulates the size of the retinal image.

Finally, the problem of the physical as opposed to apparent size of the fixation object should be mentioned. Although this problem has received recent treatment in studies of figural aftereffects, its relevance with respect to Emmert's Law has not been explored.

It seems obvious that a refined statement of Emmert's Law must await intensive treatment of the variables discussed above (i.e., apparent distance of the projection surface, apparent size and distance of the fixation figure).

#### *Other Determinants of the Size of the Afterimage*

In a series of experiments, Young investigated the effect of a number of additional variables on the size of projected AIs using spotlights to outline the AI on the projection plane. In one study Young (1952a) varied the exposure time of the stimulus object in seven steps ranging from 0.01 to 40.0 seconds. No significant variations in the size of the AI were found with variations in stimulation time. Young (1952b) also investigated several features of the projection ground. In one experiment the illumination on the projection ground was varied through five log steps. No variation in the size of the AI was found. Another experiment (1952b) utilized pictures containing strong linear perspective. AIs were projected to specified points on these pictures and compared with AIs projected to similar points on a blank screen. The surfaces with linear perspective were found to influence AI size. It is tempting to account for these results by referring to presumed changes in apparent distance resulting from the differences in geometric perspective. Unfortunately this in-

terpretation is complicated by the finding that there was little agreement between the *O*s in degree or direction of the size effect. However, an earlier study by Frank reported by Koffka (1935, p. 212) lends credence to an apparent distance interpretation. Frank used a perspective drawing of a deep tunnel. AIs projected to a phenomenally remote part of this tunnel were considerably larger than those projected to a near part. A similar effect is observed in the "Afterimage Demonstration" (Ittelson, 1952, pp. 32-33). Appropriate adjustments of the interposition indications using the overlay demonstration apparatus (Ittelson, 1952, p. 13) produce changes in the apparent distance of the projection surface and proportional changes in the apparent size of the AI.

The final study in this series (Young, 1952c) concerned the effect of large distances. In daylight AIs were projected in an open field to distances ranging from 25 to 1,250 meters. In each case obtained values were less than those expected on the basis of Emmert's Law. The hypothesis was advanced that with a brighter fixation stimulus (a square with a luminance of approximately 1,700 mililamberts), the retinal image is smaller, and consequently, the AI is smaller.

An interesting sidelight to the type of research on Emmert's Law considered so far is Oswald's (1957) study of the peripheral and central origins of AIs. Oswald uses these terms to contrast AIs in which the stimulation is confined to the retina with those involving the higher "representative" or brain centers. He cites a number of investigations, including his own in which AIs were obtained peripherally by presenting a light to an eye temporarily blinded by local pressure to the eyeball. Oswald also

reviews a number of positive and negative reports of "central" AIs following imagined (visualized) objects or objects experienced in dreams. In his main experiment *O*s "imagined" crosses or squares and then projected AIs to a screen at various distances. Most *O*s were able to achieve AIs to imagined stimuli. However, very few AIs conformed to Emmert's Law. In this regard Oswald cites several earlier reports that eidetic *O*s deviate markedly from Emmert's Law when real stimuli are employed.

With further reference to individual differences, Brengelman (1956) found deviations from Emmert's Law to be larger in his neurotic group than with normals and psychotics.

Both large individual differences, such as those reported by Oswald, as well as smaller but consistent ones are inexplicable from the standpoint of a purely physical law. As an example of the latter kind, Young (1948) reported that all of his *O*s ( $N=5$ ) yielded values falling consistently short of Emmert's Law values by a small margin. One would expect that variations due to inaccuracies of measurement alone would be randomly distributed.

#### CONCLUDING DISCUSSION

It seems to us that at least one compelling conclusion emerges from the survey we have just completed: the size-distance relationship expressed in the several formulations of the invariance hypothesis should not be assigned a unique or primary status in explanations of space perception. We have seen that this is only one of the several possible and actual relationships which are obtained. This need not cause any great consternation to those who recall the origin of the hypothesis in Euclidean geometrical principles. Although the distinction is sometimes overlooked it

should be clear that the invariance hypothesis is a psychological proposition, and not a geometrical proposition. By no stretch of the imagination can Euclid's principles be applied *directly* to space perception. Of course, the analogy is plain and very tempting, and a successful translation would have been a happy logical circumstance. Nonetheless, failure to accomplish this translation should not cause surprise.

This brings us to a second remark. A great deal of logical and experimental analysis has been aimed at clarifying the term "size." We now distinguish not only real physical size, apparent size, and retinal size, but also assumed size, apparent angular size, etc. Usually the investigator makes explicit which aspect of size perception he is dealing with. However, with regard to distance, there is often a confusion of physical distance and apparent distance. We have seen that there is no unequivocal 1:1 relationship between physical distance and apparent distance. Therefore, it is not clear how experimental investigations of the size-distance relationship are to be interpreted when apparent distance judgments are not obtained. It seems to us that all studies of size and distance should

obtain paired size-distance judgments.

This brings us to the methodological point which we mentioned earlier. Almost all of the experiments which have obtained paired size-distance judgments (including Epstein, *in press*) have done so in a successive judgment situation. We have already indicated the reasons for our dissatisfaction with this procedure. Here we wish only to reiterate the desirability for future investigation which employs a simultaneous judgment technique.

Finally, we wish to endorse a comment made earlier by Kilpatrick and Ittelson (1953) concerning individual differences. In order to assess the generality of the various size-distance hypotheses we need to look more carefully at the results of the performances of individual *O*s. In repeating some of the published research the first author has often been struck by the degree of interobserver and intraobserver variability. Results confirming various aspects of the invariance hypothesis do not allow *E* to say much about the individual *O*. In view of the "lawfulness" which is usually ascribed to the invariance hypotheses this extreme variability cannot be overlooked.

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